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THE TESTING OF GLASS CONTAINERS FOR CHEMICAL DURABILITY*

By W. E. S. Turner

Abstract

Any standard method prescribed for testing the chemical durability of glass as, for example, in the form of bottles, must be set out and subsequently applied with meticulous attention to detail. For bottles of any one composition, the alkali extracted by water can be modified by the annealing conditions and by the period and conditions of storage. Individual bottles in a set may, for these reasons, not give very closely agreeing results. Standard tests must have reference to a particular size and shape of bottle. Within the limits of time tested (5 to 6 hours), the total extraction by water is proportional to the area of surface exposed; the concentration of Na_2O in the solution obtained falls off as bottle capacity increases. Besides alkali extraction, pitting and cracking, when boiled with water, and flaking must be taken into account when assessing the chemical durability. Bottles after storage and subsequent washing usually yield a smaller amount of Na_2O to water than when new; on the other hand, the tendency to produce flaking is increased. Aqueous alcohol more readily leads to the production of flakes than water alone, a maximum effect being associated with the mixture containing approximately 40% by volume of alcohol. Alkali extraction, however, is greater with water than with the alcohol-water mixtures.

I. Introduction

Already at various times during the 19th Century, and especially in its closing years, the subject of the weathering and chemical durability of glass containers was a subject of fairly frequent consideration. In general, dark-colored bottles were, by virtue of their composition, generally recognized as of durable character; colorless glass bottles might or might not be durable, according to the compositions which the glass manufacturer employed.

In the 20th Century, the introduction of the fully automatic machine led, in the case of colorless glass bottle manufacture, to the use of glasses rapidly melted, of somewhat slow and uniform setting rate, and comparatively free from devitrification troubles, such conditions being commonly attained by a substantially higher soda content than formerly. During the earlier years of the use of automatic machines the soda content of the glass employed was often too great for satisfactory durability. Even in 1924, by which time the defects of weathering due to the use of high soda content were being generally recognized, a glass for container purposes would still be regarded as acceptable if it contained as much as 18% Na_2O. During the past ten years, however, the level of durability has been raised by the progressive changes of glass compositions employed so that nowadays a soda content of 16.5 to 15.5% is quite general, and still lower values are by no means uncommon.

In this recent period, also, purchasers of containers have, to an ever-increasing degree, come to specify that the glass shall have such and such properties; in particular, that it shall not yield more than a certain amount of alkali to the contents or become weathered when processed as a milk, pasteurized beer, or general foodstuff container. These demands on the part of the purchaser are in general entirely legitimate; but not infrequently, through lack of knowledge of the practical possibilities of glass manufacture, and also at times through ignorance of the damage brought about by their own filling processes, they ask for what is not attainable. In industries using glass containers where chemical control is exercised, methods of test and standards of durability are not infrequently asked for which indicate inadequate knowledge of the testing of glass; and glass technologists should be on their guard against such too exacting specifications.

It is the object of this paper to comment on some of the more fundamental conditions which should be understood in connection with the testing of glass containers. These comments are grouped into three main sections, namely, (1) those cases dealing with certain conditions in tests which seek to measure durability by alkali extraction, (2) those cases referring to the breaking down of the glass by pitting, flaking, and cracking, and (3) the special case of aqueous alcohol or of alcoholic preparations. The comments and data arise from work which has been in

* Presented at the Summer Meeting, Glass Division, American Ceramic Society, September 14, 1934. Revised paper received December 10, 1934.

progress in the Department of Glass Technology over a period of years.

In regard to methods of testing glass containers no detailed discussion is attempted here. Many methods have been applied: powder tests on the glass of the container, boiling the container in water or in steam, autoclave tests, and semiquantitative tests such as the use of indicators, or, in bottles for prescription purposes, solutions of alkaloid salts (*e.g.*, narcotine hydrochloride), or other readily hydrolyzed salts. Each of the tests devised by investigators in various countries may have a specific advantage and each its pitfalls. We have used or redesigned all such varieties of tests from time to time. The purchasers' special processes must often dictate the nature of the test. In the present account, the results have been obtained either by the application of the standard test worked out by the Glass Standards Committee of the Society of Glass Technology and published[1] in 1931, or, in the case of tests at temperatures below 100°, by a very slight modification of the method.

The bottles employed for investigation, except in tests relating specifically to the influence of capacity, have been flat prescription bottles of nominal 4-ounce capacity. The actual capacity was found to vary from approximately 115 to 125 cubic centimeters, according to the source of supply. In the standard test, the time of heating at 100° (in steam) is 5 hours. Some of the results, however, were obtained by heating for 6 hours, these being duly noted below.

II. Determination of Alkali Extracted; Influence of Conditions of Test

(1) Variation from Bottle to Bottle and from Observer to Observer

There are two difficulties which affect the constancy of results from bottle to bottle. One has to do with the method of determining the amount of alkali extracted by heating with water. The alkalinity of this extract is very slight, being as a rule far less than $N/100$, which is the concentration of the standard acid solution normally employed in its determination. The usual procedure is to add excess of the standard acid solution to the alkaline extract and to titrate this excess with standard ($N/100$) sodium hydroxide solution. The alkalinity of the extract is therefore obtained from difference values which bear the accumulated errors of the determination.

Apart from the need of acquiring the technique of using very dilute solutions and of indirect determination, there is not infrequently some specific effect of the glass surface arising from the process of manufacture. With bottles annealed in closed leers, the differences are, in general, slight. In leers in which the products of combustion come into contact with the glassware, a process now deliberately adopted in some factories for very good reasons, the alkaline extract may, as we have actually found, vary sometimes by as much as 100% in different narrow-mouth bottles.

In any question of specification, therefore, or in any question of dispute as between manufacturer and purchaser, it is essential that a record be available, giving the time and conditions of manufacture and the duration and conditions of subsequent storage.

Tables I and II indicate the variation found as follows: (1) the variation from bottle to bottle in a set of six tested by the same worker in the Department of Glass Technology, and (2) the variation between two observers, one in the Department of Glass Technology (A) and the other in a well-controlled glass industrial laboratory (B), using bottles drawn from a common stock.

TABLE I

ALKALI EXTRACTED BY WATER IN SIX HOURS AT 100°C

(Total Alkalinity of Individual Bottles in Cubic Centimeters of $N/100$ Concentration)

Size (oz.)	Bottle No. 1	2	3	4	5	6	Mean
1	2.39	1.99	2.18	1.93	2.24	2.09	2.14
2	3.86	4.03	4.15	4.27	4.17		4.09
(*a*) 4	5.1	5.05	5.15	5.15	5.1	5.1	5.1
(*b*) 4	5.67	5.57	5.32	5.42	5.77	5.52	5.55
(*c*) 4	4.59	4.71	4.86	4.66	4.56		4.67
6	7.06	7.36	8.04	7.29	7.12		7.37

TABLE II

TOTAL ALKALI EXTRACTED BY BOILING WATER IN SIX HOURS FROM BOTTLES OF DIFFERENT SIZES

(Alkali in Cubic Centimeters of $N/100$ Strength)

Size (oz.)	Tested at A (cc.)	Tested at B (cc.)
1	1.88	2.05
2	3.48	3.7
4	4.99	4.8
6	6.44	5.5
8	7.90	8.25
12	9.48	9.2
16	10.34	10.9

[1] "Standard Test and Specification for the Chemical Durability of 4-Oz. Flat Medicine Bottles," *Jour. Soc. Glass Tech.* (*Proc.*), **15**, 52 (1931).

It should be stated that the A results are based on the results for six bottles, whereas the B results are based on tests on only two of each size.

It will be noted that among the smaller sizes the greatest percentage errors arise from the smallest bottles. For the 2-ounce bottles the extremes vary by about 10% and the variation from the mean is 5%. In a recent test, the extreme variation between six bottles was found to be 4 to 13%, according to size (1 to 8 ounces), but for some sets of 12- and 16-ounce bottles, individual results varied much more.

In regard to the mean results of tests made simultaneously in two different laboratories, the biggest difference was 14% for the 6-ounce bottles, but only 8% for all other sizes from 1 to 16 ounces.

It seems certain, therefore, that in a test involving the determination of alkali extracted, the conditions of manufacture and storage should receive careful attention, and the details of the test itself should be carefully worked out; and, finally, a reasonably generous tolerance should be allowed in fixing any limits.

(2) Influence of Time of Extraction with Water

This subject has been investigated by a number of workers in the Department of Glass Technology[2] in 1918, very recently by Keppeler[3] and his collaborators, and by Berger.[4] For our immediate purpose, Table III illustrates the process of extraction, with time, which occurs in bottles in contact with water at 100°. In the test made, six bottles were treated simultaneously with water and at hourly intervals one was withdrawn for alkali determination. We have to assume, which can not be done with any degree of precision (see Table I above), that all the bottles would have given the same yield of alkali for the same period of extraction.

TABLE III

EFFECT OF TIME ON ALKALI EXTRACTION BY WATER AT 100°

Time of extraction (hr.)	Alkalinity in cc. $N/100$ Size of bottles		
	4 oz.	8 oz.	12 oz.
1	1.7	2.1	3.0
2	2.55	3.3	3.8
3	3.3	3.85	4.6
4	4.0	5.1	5.55
5	4.6	5.8	n.d.
6	5.25	6.3	7.1

n.d. = not done.

(3) Effect of Storage

Table IV shows the effect of storage on the alkali extracted in 6 hours by water at 100° from 4-ounce bottles received shortly after manufacture and at intervals up to 2 years and 8 months. The surface of the bottle was washed before test after each period of storage in accordance with the standard method.

TABLE IV

EFFECT OF STORAGE ON ALKALI EXTRACTED

Date of test	June 7, 1926	Sept. 17, 1926	Nov. 5, 1926	Feb. 12, 1929	Feb. 19, 1929
Alkalinity	12.09	9.27	8.17	8.5	7.8
in cc.	11.57	10.10	10.47	7.7	7.2
$N/100$	11.66	8.98	9.65	7.9	7.7
	11.89	8.44	8.80	8.0	7.7
		9.22	9.65	6.5	7.8
		9.8		8.7	7.0
Average	11.81	9.30	9.35	7.9	7.6

In considering the results of these tests, it must be borne in mind that after storage and before extraction with boiling water the bottles were all washed according to the routine procedure with dilute acetic acid, followed by distilled water. Under these conditions, storage brings about an improvement of the surface of alkali-lime-silica glasses (as far as alkali extraction is concerned), a fact which has been known for a long time.

But the result of storage is usually to produce filming on the interior surface, partly due to formation of sodium carbonate or to crystals of its compound with calcium carbonate, or again of sodium sulfate, which may be removed by washing; in part, due to a permanent film of silica, which produces iridescence when dried and can only be removed by treatment with dilute hydrofluoric acid. If the stored bottles are extracted with water without being washed, the alkali content of the extract is greater than given by the bottle when first received. As a rule, bottles with high Na_2O content in the glass give a high alkali extract after storage without washing prior to the extraction test, and a considerably reduced value, as compared with the original, when tested after being washed.

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[2] J. D. Cauwood and W. E. S. Turner, "Effect of Continued Action on Chemical Glassware of Water, Acid, and Alkali," *Jour. Soc. Glass Tech. (Trans.)*, **2**, 235 (1918).

[3] G. Keppeler and M. Thomas-Welzow, "Time Dependence of Water Attack in Glass," *Glastech. Ber.*, **11** [6], 205–208 (1933); *Ceram. Abs.*, **13** [4], 85 (1933).

[4] E. Berger, *Glastech. Ber.*, **12** [6], 189 (1934).

A lengthy investigation of the effects of storage will shortly be completed and available for publication, showing some effects of storage under different conditions of temperature, humidity, and atmospheric purity.

(4) Influence of Bottle Capacity on Alkali Extracted

It should be borne in mind that the rate of extraction from a glass surface is, among other factors, governed by the ratio between volume of extracting water and the area of the glass surface. In Tables V and VI this fact is set out in two ways.

TABLE V

EFFECT OF SIZE ON ALKALI EXTRACTED PER UNIT AREA IN SIX HOURS BY WATER AT 100°C

Bottle capacity (nominal) (oz.)	Internal area (sq. cm.)	Alkali extracted per sq. cm. in cc. *N*/100 acid
1	75	0.033
2	99	.035
4	168	.030
8	225	.029
8	283	.028
12	357	.027
16	402	.026

TABLE VI

EFFECT OF BOTTLE SIZE ON ALKALINITY PER CUBIC CENTIMETER OF LIQUID

(Six Hours Treatment with Water at 100°)

Size (oz.)	Ratio of area to capacity	Alkali in extract (mg. per cc.)
1	1.92	0.0250
2	1.65	.0230
4	1.40	.0168
6	1.24	.0142
8	1.20	.0134
12	1.02	.0108
16	0.86	.0088

Table V shows the results of a test to ascertain if, for bottles of the same composition but of different sizes made under the same conditions, this governing factor, namely, ratio of glass surface to volume of water, held good. Table VI sets out the concentration of alkali in the extract for each size of bottle.

From Table V it will be seen that (although there is a slight fall in Na_2O extracted per square centimeter) as the bottle capacity increases, it may in general be regarded as nearly constant. In accordance with this fact, with similar treatment the alkali concentration of the extract falls off as the bottle capacity increases.

These are elementary facts which are not always borne in mind when glass bottles or other forms of hollow ware are tested. Not only the actual capacity but the shape also causes variation in the ratio of volume to surface area. We have found instances of very flat, narrow bottles (such as spirit flasks) being regarded as of unsatisfactory durability, whereas somewhat larger bottles of circular cross-section, made from the same glass, have been satisfactory.

For these reasons, standard tests for bottles must be drawn up with care. Conclusions as to durability should be based on (1) the composition of the glass itself, (2) a test for durability based on the powdered glass, which is the same for all sizes and independent of surface, or (3) a test on a glass container of standard capacity and shape. If condition (3) is not observed, it becomes necessary to work out a separate standard for each size and shape of container.

III. Visible Effects of Corrosion in Glass Containers

The visible effects are several. During storage, bottle interiors develop clouding, spider-web lines, crystal formation, etc., to a degree which depends on the composition of the bottle, the degree of humidity of the atmosphere, and, above all, on the variation of temperature which governs condensation and evaporation of moisture on and from the glass surface. In this paper it is not proposed to discuss these phenomena; rather, attention will be directed to pitting of the exterior, flaking of the interior, and cracking on boiling.

(1) Pitting

This defect may arise as the result of processing glass containers used for foodstuffs, particularly milk bottles. The latter, unlike most other types of container, are collected and recharged a considerable number of times, and are subjected to washing and to steam sterilization between each charging and between each trip. Mechanical shocks to the surface during handling and transport may produce impact centers at which the surface of the glass becomes slightly crushed; and the subsequent action of steam produces visible evidence of corrosion which is enlarged with each steam treatment. This liability to pitting depends on the glass composition and on the severity of treatment in handling. Bottles made by suction-fed machines are often better than those made by gravity-fed, but only when ad-

vantage is taken of the possibilities of the suction-fed machine to make use of a glass of lower alkali content. In regard to handling, it is our experience that in dairies operated on a large scale, in which systematic and careful plant handling is employed, pitting troubles seldom arise. They are in the main confined to small, ill-equipped dairies, in which the bottles may undergo mechanical shock.

During investigations on 4-ounce prescription bottles, heated in steam from boiling water for five hours, liability to pitting has been found to be closely associated with the composition of the glass and with the amount of alkali extracted from the interior. In general, those 4-ounce bottles which yield as much as 5 milligrams of Na_2O after 5 hours boiling very often show pitting development on the exterior. Indeed, the pitting may occur sooner than 5 hours (see Table VIII). The pitting may be regarded as an auxiliary criterion of unsatisfactory durability.

(2) Flaking

Flaking is a common feature when glass is subjected to the autoclave but is also to be observed in a number of instances when bottles containing aqueous liquids are heated for some time or are maintained for lengthy periods at normal temperature.

In all cases that we have examined, the flakes which have developed in ordinary commercial glass containers have been of a highly siliceous nature. For example, a glass of percentage composition SiO_2 71.31, R_2O_3 0.51, CaO 9.26, and Na_2O 17.87 had yielded flakes containing 89% SiO_2, and in other instances flakes of approximately 100% SiO_2 have been obtained. The composition varies somewhat according to the amount of washing the flakes have received.

The importance of this flaking phenomenon lies in the fact that under some circumstances it may develop in bottles stored with liquid contents at ordinary temperatures. During the past few years we have met quite a number of such instances. Several times, for example, the defect has been associated with bottles containing spirits especially such as have been sent to Asia and kept there for some time in stock. The presence of these flakes is highly detrimental to sale, for, although the amount may be of almost negligible weight and the silica harmless, the flakes not unnaturally arouse suspicion as being of glass. When the bottle is inverted the flakes glisten in the light and their bulk, as they slowly subside, gives an impression of quantity out of all proportion to their material weight.

In connection with this subject, a good deal of investigation has been carried out in the Department of Glass Technology. Under similar conditions of storage, the most important factor controlling the production of flakes is the composition; but conditions of annealing and especially of subsequent storage are highly important.

Some of the points at issue may be illustrated by the results on four makes of 4-ounce flat prescription bottles, described as A, B, C, and D. The main constituents are quoted in Table VII.

TABLE VII

PERCENTAGE COMPOSITION

	Make of bottle			
	A	B	C	D
SiO_2	74.71	73.30	71.51	71.96
Al_2O_3 + Fe_2O_3	0.34	0.81	1.20	0.49
CaO	9.46	7.64	8.84	9.10
MgO	sl. n.d.	1.14	sl. n.d.	sl. n.d.
Na_2O	14.86	16.22	17.66	17.52
B_2O_3		0.68	0.25	

sl. = slight. n.d. = not determined.

NOTE: No determinations were made of the minor constituents, arsenic oxide, manganese oxide, sulfur trioxide, and loss at 600°.

In Table VIII are summarized a number of observations made on 4-ounce bottles of these four types. They were filled with water and subjected to heating at 100°C in steam, at first for five hours to determine, according to the standard test already referred to, the amount of alkali extracted, and subsequently for prolonged periods in order to obtain information about flaking, pitting, and cracking.

TABLE VIII

Test applied	Make of bottle			
	A	B	C	D
Na_2O extracted in 5 hr. (mg.)	2.07	1.76	3.7	3.9
Time (hr.) for initial appearance of				
(1) flakes	>100	3.5	3.0	20–24
(2) pitting	46	12	6	4
(3) cracks	100		6–24	20–24

There is no doubt that the bottles of make A are, from these tests, the most durable as they should be when judged on the basis of composition. Nevertheless, the alkali extracted after 5 hours of treatment will be seen to be a little

greater than from the bottles B. The probable explanation was forthcoming on reference to their history; for whereas bottles A were newly-made, bottles B had been made some ten months in advance and slight films were to be noted on the interior when received. The preparatory washing in the standard test would remove the slight alkaline deposit and the surface left would be slightly more resistant. At the same time, the tendency to flake was increased by reason of the siliceous film arising from the slow weathering during the months of storage.

In view of practical experience, it seemed desirable to ascertain to what extent flaking would occur at temperatures nearer to normal. Accordingly, some tests have been carried out at 30°C and 60°C. The time tests are summarized in Table IX.

TABLE IX

Time (in days) required for initial appearance of flakes							
Temp. = 30°				Temp. = 60°			
(A)	(B)	(C)	(D)	(A)	(B)	(C)	(D)
>11	6–7	8–9	9–10	4	2	3	5

At 30°C and 60°C, as at 100°C, bottles B showed a marked tendency to flake, a fact to be associated with the longer period of storage. At 60° bottles D, which on the basis of alkali extraction and pitting as well as of composition would be deemed the least durable of the series, gave visible evidence of flaking only after a longer period than A. The subject is still under investigation and a fuller discussion of it will appear later, but it may be mentioned that the flakes in part may be redissolved when the alkali concentration of the solution reaches a certain value. It is evident, however, that even bottles of excellent composition and low Na_2O extraction are liable to the production of flakes. The probability is that the use of colorless glass for containers makes this defect apparent, whereas green or dark-colored glass would mask it.

IV. The Special Case of Alcoholic Solutions

There is very little information available in published literature about the action of alcohol and alcoholic solutions on glass. Such as there is would suggest that no marked corrosive action should be expected and this would probably be the normal view on physico-chemical grounds. For whereas hydrolytic action, due to water, is clearly understood, equally marked behavior on the part of ethyl alcohol would not be predicted. In practice, the fact that whisky and other alcoholic spirits have for generations been stored in glass without suffering harm is an obviously powerful argument against any marked corrosive action on glass by ethyl alcohol.

Nevertheless, during the course of several years of observations, we have been led to question whether or not certain alcoholic solutions were not distinctly corrosive; and the receipt, within the past year, of a prescription bottle showing flaking and iridescence of the interior and the fact that, on looking into its history, we found it had contained an alcoholic preparation, brought us to the point of making a closer investigation of the subject.

TABLE X

CORROSIVE ACTION OF WATER AND AQUEOUS ALCOHOL SOLUTIONS AT 30°C AND 60°C ON GLASS CONTAINERS A, B, C, AND D, OF VARIOUS COMPOSITIONS

% Alcohol (by vol.)	Temp. (°C)	Initial time (hr.) to produce flakes				Na_2O in extract (mg.)			
		A	B	C	D	A	B	C	D
0	30	264	114–168	192–216	216–240	0.56	0.56	1.26	1.27
	60	96	48	72	120	0.86	0.60	1.72	1.98
10	30	15–21	19–21	20–21	14–20	0.08	0.12	0.20	0.20
	60	17–19	17–19	16–18	14–17	0.32	0.44	0.72	0.82
20	30	13–17	13–16	14–17	12–13	0.08	0.07	0.15	0.15
	60	12–15	12–15	12–13	10–12	0.44	0.62	1.13	1.25
40	30	2.5–5	4–5	2.5–4	2.5–3	0.06	0.08	0.10	0.09
	60	2–6	2–7	4.5–6	2–4.5	0.40	0.44	0.59	0.55
60	30	5–6	4–7	5–7	2	0.04	0.02	0.06	0.06
	60	5–7	4.5–7	4–7	2	0.06	0.10	n.d.	0.25

The bottles used for the test were the 4-ounce prescription types, A, B, C, and D, the compositions of which have already been set out (Table VII). Heating in steam could not be applied and accordingly (and what is more useful for industrial information) baths at temperatures of 30°C and 60°C were employed. The observations made were of the time needed to produce initial flaking and of the Na_2O content of the extract at

that time. The results are summarized in Table X.

Two conclusions can clearly be drawn from these results, namely, that both at 30°C and at 60°C the extraction of alkali from the glass is substantially greater by water than by aqueous alcohol; on the other hand, the readiness with which flakes are detached becomes greater as the alcohol content is increased up to a maximum of 40% alcohol by volume. It would seem, however, from these data that although the extraction of alkali by water alone was greater than by alcohol-water mixtures, for the latter there was maximum extraction by the 40% alcohol mixture when the time factor was taken into account. Further investigations were made on this point and show that the extensiveness of alkali extraction falls as the alcohol content increases. Table XI illustrates the general results obtained in the case of tests on bottles of types C and D, the period of extraction being the same in all cases, namely, 24 hours.

TABLE XI

EXTRACTION OF Na_2O FROM 4-OZ. BOTTLES, C AND D TYPES, IN 24 HOURS AT 30°C AND 60°C BY WATER AND ALCOHOL-WATER MIXTURES

	At 30°		At 60°	
Reagent	C (mg.)	D (mg.)	C (mg.)	D (mg.)
Water	0.15	0.17	0.87	0.97
20% alcohol	0.11	0.12	0.71	0.80
40% alcohol	0.07	0.09	0.61	0.66
60% alcohol	0.03	0.04	0.44	0.45

These results, in conjunction with those of Section III, emphasize the need of taking into account not only the amount of alkali extracted but also the tendency to produce flaking from the surface when considering the subject of the chemical durability of glass.

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MECHANICS OF ENAMEL SUSPENSION, I

Exchangeable Base and Viscosity Measurements on Some Vallendar Clays*

BY G. E. TERRY AND R. M. KING

ABSTRACT

The results of viscosity measurements upon untreated and electrodialyzed Vallendar clay slips, using borax as an electrolyte in varying concentrations, are set forth and discussed. Several Vallendar clays have been analyzed for exchangeable base content and the results are given.

I. Introduction

The use of Vallendar clay and borax as groundcoat conditioners and Vallendar clay and magnesium carbonate as cover-coat conditioners has become a rather general practice. The modern acid-resisting enamel, however, can not be properly conditioned or "set up" by using borax or magnesium carbonate. Such electrolytes as ammonium and potassium alum, ammonium carbonate, and sodium aluminate have been found satisfactory for this type of enamel.

In view of the many problems arising in connection with clays and other factors in the setting-up of enamels, it was decided to make a thorough study of the general problem of enamel conditioning.

Enamelers variously attribute the behavior of Vallendar clay to (1) its floating power, (2) its ability to prevent or minimize fishscaling, (3) its opacifying power, or (4) its ability to maintain the stability of the enamel slip.

Soil chemists have shown that the "clay" or colloidal fraction of soils varies markedly in properties depending on the so-called exchangeable or replaceable bases. These bases comprise that portion of the base material which is adsorbed by the colloidal particles and which can be removed by leaching with an acid, a neutral salt, or by electrodialysis. If the replaceable base constituent is present in the form of sodium ions, the properties of the colloid will be different from the properties of the same clay if the replaceable

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TABLE I

RELATIVE VISCOSITY VALUES: BORAX-CLAY-WATER MIXTURES

(U = untreated clay E = electrodialyzed clay)
(T = too thick to flow)

Milli-equivalents borax per 70 gm. clay	Time of standing (hr.)	Clay 1		Clay 2		Clay 3		Clay 4		Clay 5		Clay 6	
		U	E	U	E	U	E	U	E	U	E	U	E
0	1	1.5	1.69	1.43	T	1.52	T	1.78	T	1.40	T	1.45	T
	24	1.5	T	1.48	T	1.61	T	1.83	T	1.41	T	1.43	T
	168	1.5	T	1.52	T	1.65	T	1.90	T	1.44	T	1.49	T
2.5	1											1.38	T
	24											1.35	T
	168											1.33	T
5.0	1				2.02				1.53			1.50	2.42
	24				1.74				1.60			1.39	1.73
	168				2.07				1.69			1.36	2.92
7.5	1											1.42	1.20
	24											1.40	1.20
	168											1.39	1.19
10.0	1				1.36				1.42			1.47	1.25
	24				1.39				1.43			1.46	1.27
	168				1.39				1.44			1.43	1.27
15.0	1	1.5	1.37	1.42	1.38	1.52	1.41	1.50	1.43	1.44	1.42		
	24	1.5	1.37	1.42	1.39	1.52	1.47	1.55	1.50	1.45	1.47		
	168	1.5	1.36	1.48	1.40	1.53	1.47	1.55	1.50	1.44	1.47		
20.0	1											1.51	1.27
	24											1.51	1.31
	168											1.50	1.30
25.0	1	1.49	1.38	1.42	1.39	1.48		1.53	1.50	1.45	1.45		
	24	1.48	1.38	1.42	1.42	1.48		1.62	1.61	1.45	1.51		
	168	1.50	1.45	1.48	1.45	1.48		1.62	1.65	1.45	1.51		
30.0	1	1.44	1.39	1.42		1.47	1.45	1.53		1.44			1.28
	24	1.45	1.45	1.42		1.47	1.60	1.60		1.44		1.57	1.36
	168	1.49	1.45	1.48		1.46	1.67	1.60		1.45		1.51	1.36
35.0	1	1.43	1.40	1.41		1.44	1.48	1.53		1.45	1.45		
	24	1.44	1.45	1.42		1.44	1.63	1.56		1.44	1.53		
	168	1.49	1.45	1.48		1.50	1.70	1.56		1.82	1.53		
40.0	1	1.43	1.40	1.41		1.44	1.54	1.51		1.45	1.45		1.31
	24	1.44	1.45	1.42		1.44	1.60	1.54		1.45	1.58	1.57	1.29
	168	1.68	1.45	1.48		1.59	1.70	1.53		1.82	1.58	1.54	1.43
45.0	1	1.42	1.41	1.41	1.44	1.44		1.51	1.59	1.45	1.45		
	24	1.44	1.45	1.42	1.49	1.44		1.53	1.64	1.45	1.58		
	168	1.68	1.45	1.62	1.50	1.63		1.81	1.71	1.82	1.58		

base content is all potassium, calcium, or hydrogen ions. If replaceable bases consist of a mixture of ions, which is the case in most clays, this is the cause of an annoying variation in clays. It is therefore desirable for uniform results in working with a clay to have the exchangeable base present as a single ion. For this study, the hydrogen clay has been used as a standard of comparison. This was prepared by electrodialysis.

II. Procedure

Electrodialysis is usually carried out in a cell similar to an electrolysis cell, but different in that the clay or other colloid to be treated is placed in a separate compartment whose walls are permeable to ordinary ions but not to the finest clay particles or ions. Such a cell consists of three parts, *viz.*, the cathode compartment, the anode compartment, and the compartment for the colloid. Sometimes the two latter are the same. Cells similar to those described by Bradfield[1] and Mattson[2] have been used in this study. When clay is electrodialyzed the essential proc-

[1] R. Bradfield, "An Inexpensive Cell for Purification of Colloids by Electrodialysis," *Ind. Eng. Chem.*, **20**, 79–80 (1928).

[2] Sante Mattson, "Electrodialysis of the Colloidal Soil Material and the Exchangeable Bases," *Jour. Agric. Research*, **33** [6], 553–67 (1926).

esses occurring are as follows: The adsorbed basic ions migrate to the cathode and form hydroxides in the cathode region. At the same time acids are formed with the clay and other anions, thus forming the acid or unsaturated clay. The alkaline solution may be titrated to determine the replaceable bases.

Several samples of Vallendar clays of one-thousand gram batches were screened wet through

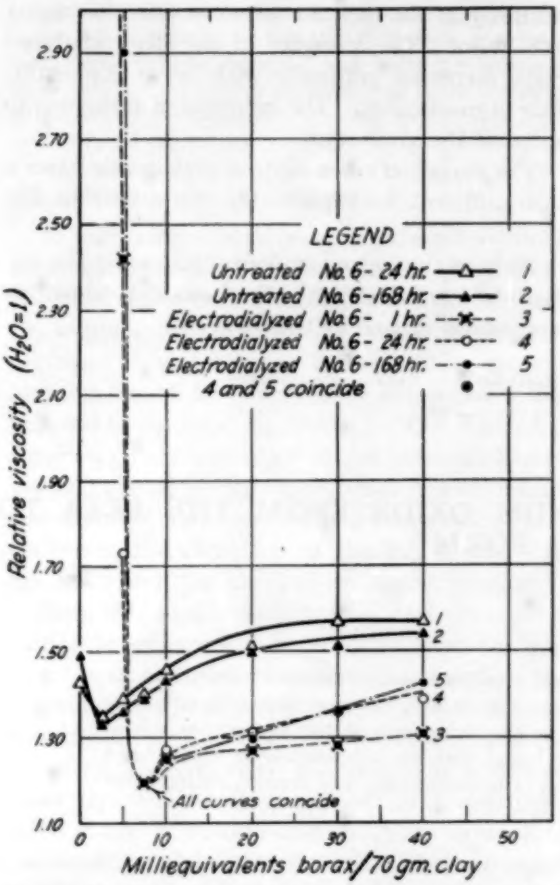

FIG. 1.—Relative viscosity *vs.* borax concentration (clay No. 6).

a 200-mesh screen to remove coarse particles and the fines were electrodialyzed 100 hours at 125 volts direct current and 0.2 to 0.4 ampere. After this treatment a negligible amount of the replaceable bases remained in the clay. The H-clay thus prepared was made into slips containing 120 grams clay and 400 grams water, or 23.08% clay.

NOTE: Slips containing 70 grams clay to 400 grams water, the approximate concentrations of clay in water-enamel slips, were too thin to show viscosity differences with the viscometer available.

Borax was added to these slips in varying amounts and their viscosity was determined with a Mariotte tube viscometer with a $^3/_{32}$-inch orifice. Corresponding slips were made of the original clays and were similarly tested (see Table I).

In addition to the viscosity, the replaceable bases in the clays were determined with a special analytical cell as described by Bradfield[3] (see Table II).

TABLE II

	Clay No. 1 U	Clay No. 2 U	Clay No. 3 U	Clay No. 4 U	Clay No. 5 U	Clay No. 6 U
*Exchangeable bases milliequivalents/ 100 gm. air-dry clay	9.3	9.8	9.9	10.0	10.4	9.1

* Also includes soluble salts.

III. Discussion of Data

(1) Viscosity

The main purpose in obtaining viscosity data was to determine the influence of borax on viscosity at and near plant-practice proportions. There are usually about 7.5 grams (39.3 milliequivalents) to 70 grams of clay. Consequently, concentrations used clays first studied were more evenly distributed, a concentration of about 40 milliequivalents. Later some shifts in concentrations were made in order to locate minimum points.

Data for No. 6 clays only have been plotted (Fig. 1), and data for other clays have been discussed in relation to this. Data obtained on untreated clays after standing one hour were not considered reliable and were not plotted. It seems that the untreated clay does not disperse so quickly as the electrodialyzed clay.

Number 6U reaches a minimum viscosity at about 2.5 milliequivalents of borax. The viscosity then increases gradually through the range of plant-practice concentrations. Number 6E reaches a minimum at 7.5 milliequivalents. The effect of aging is to decrease the viscosity slightly in the case of the untreated clay and to increase it slightly in case of electrodialyzed clay.

From the data obtained for the other clays, it is difficult to say where the first minimum is. (Some of these clays seem to go through a series of maxima and minima.) It is probable, however, that there is a minimum corresponding to that of No. 6 at about the same concentration.

[3] R. Bradfield, "A Simplified Cell for Determining the Electrodialyzable Base Content of Soils and Permutites," *Jour. Amer. Soc. Agron.*, **19** [11], 1015 (1927).

Again, in view of the unreliability of the data on the untreated clays after standing one hour, only the difference between 24 hours and 168 hours standing shall be considered. It should be noted first, however, that the viscosity at the end of the 24-hour period changes very little with increase in borax concentration. In all cases of aging 168 hours, except for No. 6, the viscosity increased abruptly before or at the plant-practice concentration. In the case of electrodialyzed clays, the increase in viscosity was gradual as the borax approached the plant-practice concentration.

(2) Replaceable Bases

In Table II are given the amounts of replaceable bases removed from clays as received. These values do not vary enough to explain the variation in viscosity. It is possible that the nature of the replaceable bases is a factor.

(3) Plant Tests

Clays No. 1 and No. 6 are being used with satisfaction. Clay No. 2 is reported as giving a greasy surface condition and clay No. 4, a scum. No report has been received to date on No. 5.

IV. Summary and Conclusions

In general, the behavior of these clays toward increased concentrations of borax and aging is the same. The viscosity of untreated clays did not materially change with borax concentration after aging 24 hours but increased markedly and abruptly at the higher concentrations after aging 168 hours. The viscosity of the electrodialyzed clays increased gradually with borax concentration in most cases. The influence of aging was to increase the viscosity.

The variation in amounts of replaceable bases is not sufficient to explain the variations in viscosity.

None of the factors studied accounts for the surface defects found in the fired enamels which are apparently caused by the clay.

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THE TRANSFORMATION OF ALUMINUM OXIDE FROM THE BETA TO THE ALPHA FORM*

By John Gallup

Abstract

Until recently it had not been known that beta alumina could be converted directly to the alpha form without going through the molten state. This paper is the report on an investigation which shows that beta alumina changes rapidly to the alpha form at temperatures as low as 1300°C when heated in a vacuum. It was also found that the temperature at which rapid conversion starts rises successively in atmospheres of hydrogen, air, and argon. Petrographic identifications were checked by density determinations.

I. Introduction

(1) Literature

Alpha alumina is the form of aluminum oxide normally formed by heating aluminum oxide to high temperature (about 1000°C) and is the form of the natural mineral corundum. In 1916, Rankin and Merwin[1] discovered a beta form produced occasionally in alumina charges which had been molten and then cooled slowly. Morey[2] states that it forms invariably in the alumina field of the systems MgO–Al_2O_3–SiO_2 and Na_2O–Al_2O_3–SiO_2. It has always been considered as being monotropic, persisting indefinitely when once formed and never changing to corundum. Morey,[2] however, states that in recent work in the Geophysical Laboratory on the K_2O–Al_2O_3–SiO_2 system it has been found that beta alumina sometimes separates instead of corundum and afterward slowly changes to corundum. Brownmiller and Bogue[3] also found the beta form to be the one separating in the system CaO–Na_2O–Al_2O_3. Stillwell[4] claims that the presence of Na_2O is essential to the formation of beta alumina. Gottfried,[5] working on mate-

* Presented at the Annual Meeting, American Ceramic Society, Buffalo, N. Y., February, 1935 (Refractories Division). Received January 25, 1935.

[1] G. A. Rankin and H. E. Merwin, "The Ternary System CaO–Al_2O_3–MgO," *Jour. Amer. Chem. Soc.*, **38**, 570 (1916).

[2] G. W. Morey, "The Crystalline Form of Alumina," *Bull. Amer. Ceram. Soc.*, **13** [3], 79 (1934).

[3] L. T. Brownmiller and R. H. Bogue, "The System CaO–Na_2O–Al_2O_3," *Amer. Jour. Sci.*, [5], **23**, 501 (1932).

[4] C. W. Stillwell, "The Color of the Ruby," *Jour. Phys. Chem.*, **30**, 1445 (1926).

[5] C. Gottfried, "The Crystal Lattice of Beta Alumina" (Über den Feinbau des β-Korunds), *Z. Krist.*, **66**, 393–98 (1928).

rial (supplied by W. Eitel) containing 2.56% Na_2O, checked earlier results of Hendricks and Pauling[6] on the space group and unit cell of beta Al_2O_3 and found it to have an open, honeycomb structure similar to that found for beryl by Bragg and West.[7] Beryl $Be_3Al_2(SiO_3)_6$ may contain as much as 7% alkali in the crystals.[8] Bragg, Gottfried, and West,[9] working on the structure of beta alumina by X-ray methods, used crystals of beta alumina[10] which, on the basis of density determinations and chemical analysis, they decided had the unit cell composition $NaAl_{22}O_{34}$, roughly 2.57% Na_2O. They postulate a structure similar to that of $MgAl_2O_4$.

Alpha alumina is trigonal, uniaxial negative, $\alpha = 1.760$, $\omega = 1.768$, density = 3.8 to 4.0.[11] Beta alumina is hexagonal, uniaxial negative, and both the indices of refraction and the density are lower than in the case of the alpha form. For beta Al_2O_3, $\alpha = 1.63$ to 1.65, $\omega = 1.665$ to 1.680, and the density = 3.31.[11]

(2) Scope of the Investigation

In some recent work involving the petrographic examination of heat-treated alumina powders for the presence of beta alumina, it was noticed that in samples which had contained appreciable amounts of beta alumina before heating no beta alumina could be found after firing for a few minutes in hydrogen at 1700°C. This somewhat surprising result, that all of the material heated gained the optical characteristics of alpha alumina was checked by density determinations. These confirmed the identities of the initial and final materials and thus checked the transformation.

Since this rapid conversion is in direct contradiction to what might be expected from the previous work of various experimenters listed at the beginning of this paper, it was decided to investigate the subject further. Furthermore, since the transformation occurred so readily in hydrogen while reported to happen slowly and with difficulty in air, it was deemed desirable to work in the direction of heating crystals of beta alumina in different atmospheres and at different temperatures in order to determine what influence the heating atmosphere had on the rate of conversion and the temperature at which conversion occurred.

(3) Material

The alumina[12] used in the investigation contained about 90% of the beta form and about 10% of the alpha or corundum form. The beta crystals were flat plates (Fig. 1(*a*)), which extinguished between crossed nicols in parallel polarized light but gave the stationary black cross of a uniaxial basal section interference figure in convergent light (Fig. 1(*b*)). The indices of refraction checked with those reported for beta alumina. The density of the material as a whole was 3.36; that for beta alumina[11] is reported as 3.31. Strangely enough, a chemical analysis[13] for Na_2O gave a value of 2.56% which checks exactly with the values given by both Gottfried[5] and Bragg,[9] etc., who worked on materials from separate sources. This suggests a constant soda content for beta alumina.

II. Procedure and Results

All material was ground to pass a 200-mesh screen before heating, since a preliminary heating of a large mass had shown transformed material only on the outer surface where it had been in contact with the furnace atmosphere of hydrogen.

Indices of refraction were determined by immersion in oils of known indices. The Becke line[14] method was checked by use of the method of oblique illumination.[15] The oils used were mixtures of cinnamon oil and alpha monobromnaphthalene for the range of indices from 1.64 to 1.66, mixtures of alpha monobromnaphthalene and methylene iodide for indices from 1.66 to 1.74, and methylene iodide with sulfur for indices above 1.74. After measuring accurately the indices of refraction of the crystals of several firings of material, it became apparent that immersion in one oil of an index of refraction of 1.72 could safely be used to estimate the relative amounts of alpha and beta alumina present. All batches, however, were also immersed in oils with indices of 1.70 and 1.74 to guard against the undetected appearance of a crystal with an index of refraction intermediate between the high of 1.68

[6] S. B. Hendricks and L. Pauling, "The Unit Structure and Space Group Symmetry of Beta Alumina" (Die Struktureheit und Raumgruppen-Symmetrie von (Beta-Aluminiumoxyd), *Z. Krist.*, **64**, 303–308 (1927).

[7] W. L. Bragg and J. West, "The Structure of Beryl," *Proc. Royal Soc.*, [Ser. A], **111**, 691 (1926).

[8] N. H. Winchell and A. N. Winchell, Elements of Optical Mineralogy, Part II. Descriptions of Minerals, p. 272. John Wiley & Sons, Inc., New York, 1927.

[9] W. L. Bragg, C. Gottfried, and J. West, "The Structure of Beta Alumina," *Z. Krist.*, **77**, 255 (1931).

[10] Prepared by the Norton Company.

[11] A. N. Winchell, Microscopic Characters of Artificial Minerals, p. 188. John Wiley & Sons, Inc., New York, 1931.

[12] Supplied by A. A. Klein, Norton Co., to whom the author wishes to express his thanks.

[13] Analysis made by H. Swanson, RCA Manufacturing Co., Inc., RCA Radiotron Division.

[14] A. N. Winchell, Elements of Optical Mineralogy, Part I. Principles and Methods, pp. 71 and 72. John Wiley & Sons, Inc., New York, 1928.

[15] *Ibid.*, p. 72.

for beta alumina and the low of 1.76 for alpha alumina.

Density determinations were made by the pycnometer bottle method using distilled water as the liquid and boiling it under reduced pressure at room temperature.

body, errors in temperature measurement should not exceed ±10°C, except in the case of the determination in argon.

(1) Firing in Hydrogen

The firing in hydrogen was conducted in an

FIG. 1 (*a*).—Flat, plate-like crystals of beta alumina (magnification 500 ×).
(*b*).—Interference figure from a crystal of beta alumina. The fixed black cross of a basal section proves that the crystals are basal plates.
(*c*).—Fibrous bundles of crystals obtained by heating material in (*a*) to 1300°C for an hour in hydrogen; not alpha Al_2O_3, but a transition form between beta and alpha. Extinction parallel to length of fibers; crossed nicols (magnification 500 ×).
(*d*).—Crystals of alpha Al_2O_3 formed from beta Al_2O_3 by heating 10 minutes in hydrogen at 1800°C. Note alignment of crystals which suggests the manner of their formation from the intermediate form shown in (*c*). Extinction parallel to long dimensions of crystals; crossed nicols (magnification 500 ×).

All temperatures were measured on the hot sample using a disappearing-spot type optical[16] pyrometer which had been recently calibrated. Since all firings except that in argon were made under conditions approximating those of a black

electric resistance furnace of the tubular type through which a stream of hydrogen passed. The powdered material was heated in a small molybdenum boat which was pushed into a water-jacketed metal cooling chamber at the end of the firing period. This produced almost instantaneous quenching conditions.

[16] Pyrometer Instrument Co., 50 Howard Street, New York City, N. Y.

Samples of beta alumina fired ten minutes at 1800°, 1700°, 1600°, and 1500°, respectively, exhibited only crystals having the optical characteristics of alpha alumina. Density determinations gave values varying from 3.9 to 4.0, correct values for alpha alumina. Material heated ten minutes at 1400°C was nearly all converted to alpha crystals with traces of beta persisting. Crystals of the transformed alumina are shown in Fig. 1(*d*). Material heated ten minutes at 1300°C showed practically no conversion. Continuing the heating for an hour at 1300°C produced a splitting up of the large flat crystals of beta into flat plates of needle-like crystals which still had the lower indices of refraction of beta alumina. They are evidently an intermediate form between beta and alpha. Their fibrous structure is shown in Fig. 1(*c*). The plates extinguish parallel to the length of the fibers between crossed nicols. Material fired three hours at 1200°C showed no appreciable increase in the amount of alpha present and material fired sixteen hours at 1100°C showed no increase in alpha alumina.

Apparently beta alumina does not convert to the alpha form with any rapidity below 1300°C in hydrogen. At 1400°C the conversion is rapid, practically complete in a ten-minute firing period.

(2) Firing in Air

Material fired an hour in an electric muffle furnace at a temperature of 1300°C showed no signs of conversion of the beta crystals. A sample heated ten minutes in a gas-fired pot furnace with as oxidizing an atmosphere as could be obtained at a temperature of 1400°C showed little or no conversion. A sample heated ten minutes in a like manner at 1500°C showed no appreciable increase in the amount of alpha crystals present. Continuing the heating for an hour at this temperature produced little if any further conversion. Crystals heated ten minutes at 1600°C in this atmosphere, however, were nearly all converted to alpha alumina. Evidently conversion does not start in air until nearly 300° higher than the temperature required in hydrogen.

It is possible, also, that the temperature of rapid beta-to-alpha conversion may be even higher in an electric furnace operating in air than it appeared to be in the air-gas furnace since the furnace atmosphere in this latter case must always contain incompletely burned gas. Even the products of complete combustion may differ from air in their influence on the temperature of conversion. Therefore, it can not be said that these results flatly contradict the work of previous experimenters; rather, they tend to explain why the beta-to-alpha conversion of alumina was so long unobserved.

(3) Firing in Vacuum

The beta-alumina powder contained in a small molybdenum boat was fired in an electric resisttance furnace operating in a vacuum which averaged about 40 microns of mercury pressure during the firing operation.

Beta-alumina samples fired at 1800°, 1700°, 1600°, 1500°, and 1400°C, respectively, for ten-minute periods showed complete conversion to the alpha form. A sample fired 10 minutes at 1300°C was partially converted to alpha alumina. It exhibited, however, the curiously broken structure of needle or lathe-like forms noted in material fired an hour in hydrogen at 1300°C. Apparently conversion goes forward slightly faster in vacuum than in hydrogen but at about the same starting temperature.

(4) Firing in Argon

The beta alumina was suspended in water and a thick coating transferred by brushing to a tungsten spiral of 15 mil wire. This was mounted in a glass bulb so that current could be supplied to heat it. The bulb was then evacuated and pure argon drawn in to reach a pressure of approximately one atmosphere. The current was turned on and increased until the alumina fused in drops on the wire. All of the drops contained only crystals of alpha alumina. Another tube was tried with only sufficient current to raise the temperature, as read on the surface of the coated wire by the optical pyrometer, to 1720°C. Optical examination showed that all of the alumina had been converted to the alpha form. A third trial heated 10 minutes at 1680° gave crystals which were nearly all of the alpha form. A few beta crystals, however, were present. Another sample heated ten minutes at 1650°C showed the peculiar broken structure characteristic of the transition from beta to alpha. Both beta and alpha forms were present. A sample heated at 1600°C for ten minutes showed no signs of conversion of the beta alumina to the alpha form. It is to be recognized that a surface measurement of tem-

perature such as this gives a value somewhat lower than that true temperature and it is, therefore, safe to say that beta alumina is not converted at all rapidly to the alpha form in an atmosphere of argon at one atmosphere of pressure at temperatures below 1650°C.

III. Chemical Analysis of Transformed Al_2O_3

Since the soda is indicated as playing an important rôle in the structure of beta alumina it appeared desirable to discover what happened to it when the beta alumina was transformed to alpha alumina. Accordingly, part of the sample from which the first chemical analysis had been made was heated to 1800°C for 10 minutes in hydrogen. A sodium determination on this converted material showed only 0.445% Na_2O remaining as compared with 2.56% Na_2O in the material in the unconverted beta form.

This large loss of sodium oxide by the material during conversion to the alpha form coupled with the surprisingly uniform sodium content of beta-alumina samples leads one to suspect that beta alumina owes its loose structure, in part at least, to the presence of alkalis in its expanded lattice and that it can not convert to the denser alpha form until these alkalis have been largely expelled. This hypothesis is also borne out by the fact that conversion occurs at the lowest temperatures (1300°C) in a vacuum and in hydrogen gas, both of which surroundings offer but little resistance to the escape of the sodium. The temperature of conversion is still further raised from that in air (1600°C), where it is fairly difficult for alkalis to escape, to a sensibly higher one (1650°) in argon, where the escape of the sodium is considerably repressed by the inert gas at atmospheric pressure.

IV. Conclusions

(1) Beta alumina converts rapidly to the alpha form in hydrogen or in a vacuum starting at temperatures as low as 1300°C and increasing in velocity of conversion as the temperature is raised, until at 1400°C the transformation is practically complete in a firing period of ten minutes.

(2) The temperature of rapid conversion in the atmosphere secured in a gas-air pot furnace is much higher than in either hydrogen or a vacuum. It appears to start at about 1600°C.

(3) The temperature range of rapid conversion in argon at atmospheric pressure starts at approximately 1650°C, somewhat higher even than that in the atmosphere of the pot furnace. Conversion to the alpha form is not complete in a ten-minute firing period at temperatures below 1700°C.

(4) Heated just to the temperature at which rapid conversion starts, beta alumina goes through a transition stage of long, lathe-shaped crystals before changing to the characteristic crystals of alpha alumina. These bundles of needles have parallel extinction and their elongation seems to carry over in the alignment of the final crystals of alpha alumina.

(5) It seems probable that the expanded lattice and the low density of beta alumina are due to the inclusion of alkalis within the lattice. Beta alumina can not convert to alpha alumina until the alkalis have been largely expelled by heating in an atmosphere and at a temperature which will permit their ready escape. In addition, it is worth noting that three different beta aluminas contained approximately equal amounts of sodium as shown by chemical analyses reported by Gottfried[5] and Bragg,[9] and this paper.

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THE CONVERSION OF QUARTZ INTO CRISTOBALITE BELOW 1000°C, AND SOME PROPERTIES OF THE CRISTOBALITE FORMED*

By Sandford S. Cole

Abstract

An investigation of the conversion of quartz into the higher temperature forms of silica was made in order to establish whether cristobalite or tridymite is first formed in the temperature range 850 to 1050°C. The results of over 800 determinations established the fact that sodium silicate promotes the conversion and is materially superior to other fluxes reported in the literature.

Cristobalite forms before tridymite in the conversion of quartz at 890 to 900°C. The rate of conversion is dependent upon time and temperature. The cristobalite in the temperature range studied was metastable and slowly converted to tridymite. The inversion of the low to the high form of cristobalite occurred at 250 to 260°C on heating. The refractive index was found to be in agreement with that for cristobalite formed at higher temperatures. The conversion is believed to be one of a solid-liquid type, and a theory to explain the formation of cristobalite before tridymite is offered, based on the crystal lattice structure changes required to develop the two high-temperature forms of silica from quartz.

I. Introduction

The formation of cristobalite might precede that of tridymite at temperatures just above the stable range of quartz. This expectation is justified by Ostwald's rule,

> In all reactions the most stable state is not straightway reached, but the next less stable, or that state which is the least stable of the possible states.

Further, it will be shown that the structural changes necessary in the crystal lattices in going from quartz to cristobalite appear to be less than those required in the change from quartz to tridymite.

The conversion of quartz into cristobalite at relatively low temperatures has not been reported in the literature. The formation of cristobalite from heated quartz crystals without flux will occur in the temperature range of 1100 to 1400°C, according to other investigators. A survey of the literature established 1250°C for the lowest temperature of complete conversion of quartz into cristobalite in absence of any flux. The formation of cristobalite and tridymite was frequently carried out with large quantities of flux. The cristobalite formed below 1470°C and converted slowly to tridymite.

Note: In this paper the term "inversion" will indicate the rapid change in physical state of one crystalline form of silica, such as alpha to beta quartz. The term "conversion" will indicate the sluggish change of one crystalline form of silica into another, such as quartz into tridymite.

II. Scope of Investigation

The objects of the investigation were to determine (1) if quartz could be converted below 1050°C into cristobalite; (2) if cristobalite is first formed in the conversion; (3) if cristobalite that is formed at lower temperatures differs materially in physical properties from the high-temperature product; and (4) if the cristobalite so formed is relatively stable with respect to conversion to tridymite.

The physical properties which were considered to be most suitable for experimental study were specific gravity, thermal expansion (inversion temperature), and optical properties.

III. Materials Investigated

The quartz was Oriskany sandstone from central Pennsylvania, ground to pass a 200-mesh screen (0.074-millimeter opening). The sample analyzed

	(%)
SiO_2	99.87
Al_2O_3	0.12
Fe_2O_3	0.01
CaO, MgO, and alkalis	0.01

In a preliminary study various fluxes were used, but the best material found was sodium silicate. A rather complete range of the dry silicates was procured having the following compositions:

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Brand	$Na_2O:SiO_2$	Na_2O (%)	SiO_2 (%)	H_2O (%)
A	1:3.25	22.9	74.4	11.0
B	1:3.22	19.4	62.5	17.5
C	1:2	33.0	66.0	1.0
D	1:2	27.5	55.0	17.5
E	1:1	29.0	28.2	42.8

IV. Method of Investigation and Testing

The powdered quartz was blended with the sodium silicate which had been dissolved in water, and test pieces (10 by 10 by 20 millimeters) were molded by hand tamping. The silicate was dissolved in water in order to assure complete coating of all the grains with the reagent. The bars were heated in an electric-resistance furnace which was regulated by a temperature controller actuated by a photoelectric cell. The variation in temperature of the furnace was less than 5°C.

The apparent specific gravity was determined for all tests after boiling the samples for two hours in water and was calculated from the dry and suspended weights obtained. In certain cases true specific gravity determinations were made using the pycnometer bottle method. The apparent specific gravity was found to be about 0.01 to 0.02 less than the true specific gravity.

Petrographic examination was carried out with immersion oils in determination of the index of refraction of the products. The thermal expansion measurements were made with an apparatus similar to that described by the writer.[1]

V. Results Obtained

(1) Specific Gravity and Microscopic Examination

Since over 800 determinations were made involving various amounts of flux, time of heating, and temperatures, the data would be too extensive to present in their entirety. A selected group of results will be given in order to show the general trend of the data.

TABLE I

APPARENT SPECIFIC GRAVITY OF THE TEST PIECE AFTER HEATING WITH 2% SODIUM SILICATE

Sodium silicate	Hours heated	Temperatures (°C) 900	925	950	975	1000
(B)	10	2.61	2.59	2.48	2.46	
	20	2.55	2.46	2.45	2.40	2.39
(C)	10	2.57	2.51	2.35	2.34	
	20	2.44	2.35	2.34	2.33	2.33
	30				2.33	2.33
(E)	10	2.49	2.51	2.35	2.34	
	20	2.44	2.35	2.33	2.32	2.31
	30				2.30	2.30

[1] See Bibliography, p., 124 Ref. 23.

In order to establish information concerning the effect of size of grain on the rate of conversion, the quartz was sieved through a 325-mesh screen and mixed with 2% of (B), which is the silicate that gave the least conversion as shown by Table I. The results of this experiment are given in Table II.

TABLE II

APPARENT SPECIFIC GRAVITY OF TEST PIECES MADE WITH −325-MESH AND 2% (B) SODIUM SILICATE AFTER HEATING

Hours heated	Temperature (°C) 900	925	950	975	1000
10	2.47	2.39	2.37	2.35	2.34
20		2.36	2.35	2.33	2.32

Petrographic examination of the samples from the various heating tests showed the presence of quartz in all samples heated below 950°C. Quartz was found in (B) mixes at all temperatures, except 975,C° and 1000°C for 20 hours with −325-mesh material. Cristobalite had started to form at 900°C after 20 hours' heating with 2% of any silicate used The index of refraction of the cristobalite formed was 1.485 to 1.486, which is nearly the mean value of 1.487 and 1.484 as reported in the literature.

In order to ascertain if the cristobalite would change to tridymite at temperatures below 1000°C, a series of samples was heated for longer periods of time using 4% sodium silicate. The results are given in Table III.

TABLE III

APPARENT SPECIFIC GRAVITY OF QUARTZ TEST PIECES AFTER HEATING FOR VARIOUS PERIODS OF TIME WITH 4% SODIUM SILICATE

Sodium silicate	Hours heated	Temperatures (°C) 950	1000
(A)	30	2.34	2.31
	60	2.33	2.31
	90	2.29	2.29
(D)	30	2.30	2.30
	60	2.26	2.31
	90	2.27	2.26
(E)	30	2.37	2.28
	60	2.35	2.29
	90	2.34	2.26

Petrographic examination of the samples showed that after 30 hours the cristobalite would begin to convert to tridymite, but complete conversion was not attained even after 90 hours although the specific gravity data would tend to show complete conversion, the specific gravity of tridymite being 2.27.

True specific gravity determinations were made on samples heated at several different temperatures which showed complete conversion to cristobalite. Results for three temperatures are given in Table IV.

TABLE IV

TRUE SPECIFIC GRAVITY OF SAMPLES SHOWING PRACTICALLY 100% CONVERSION

Mix	Hours heated	Temperature	True specific gravity
3% (B)	20	950°C	2.354
4% (D)	30	1050°C	2.359
2% (A)	25	1550°C	2.360

(2) Rate of Conversion

A study of the rate of conversion (reaction) at constant temperatures, as measured by thermal expansion, was made. The results for two

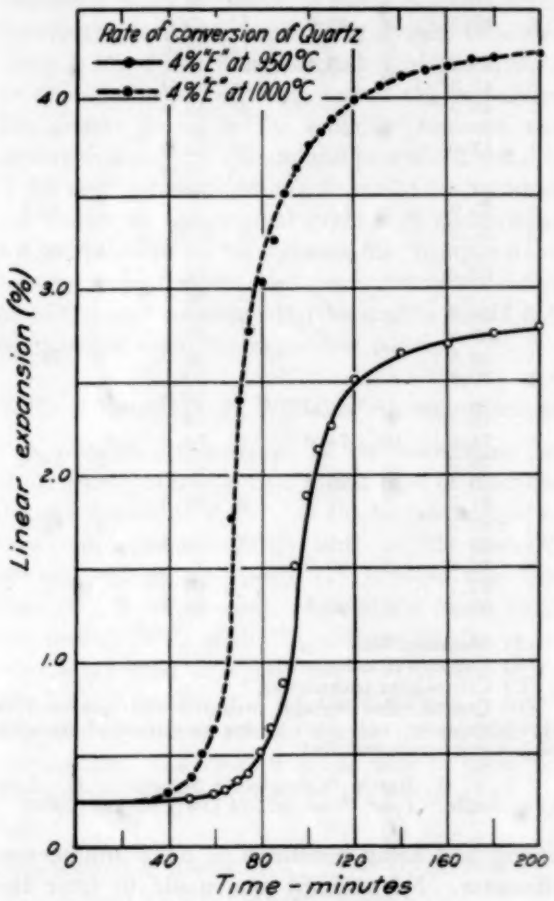

FIG. 1.

temperatures are shown in Fig. 1. This is a typical autocatalytic curve, *i.e.*, the kind of curve produced when the product acts as a catalyst to speed up the reaction. It shows that the cristobalite, after forming, serves as points of grain growth and accelerates further conversion.

(3) Thermal Expansion of Product

Thermal-expansion determinations on various mixes gave 250 to 260°C as the inversion point of low cristobalite to high, with a linear expansion of 1.6%. Typical curves of the expansion results are shown in Figs. 2 and 3.

VI. Discussion of Data

The change in specific gravity shows that the use of sodium silicate can bring about a marked conversion of quartz above 870°C. Data (not reported here) showed that even 1% (B) (0.2% Na_2O) will promote this conversion. The cristo-

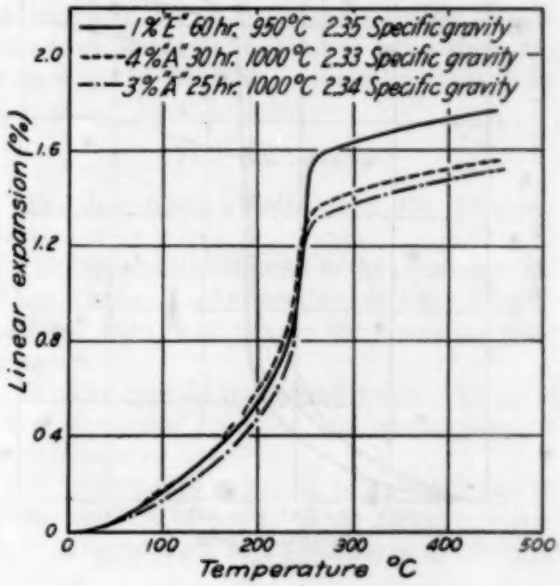

FIG. 2.

balite is similar in optical properties to material formed above 1470°C. About half the samples which had specific gravity values less than 2.40 were examined for cristobalite. The cristobalite formed before the tridymite; in fact, some samples were free of tridymite with nearly 100% conversion of quartz into cristobalite.

The study of the conversion rate showed that the reaction requires about one hour to start at 950°C and at this temperature slows down after 2 hours. The transformation depends in part

upon the presence of cristobalite to seed the crystal formation in a manner similar to other grain-growth phenomena and polymorphic transformations. At 1000°C, the reaction goes faster and proceeds further, which is entirely in agreement with other data on rates of reaction depending upon heat to accelerate the reaction.

The thermal expansion data on samples fired at different temperatures and with various quantities of sodium silicate showed that inversion of low to high cristobalite occurred at 250 to 260°C. The point of inflection appears at 255°C. This inversion temperature appears to be the characteristic one for cristobalite produced with sodium

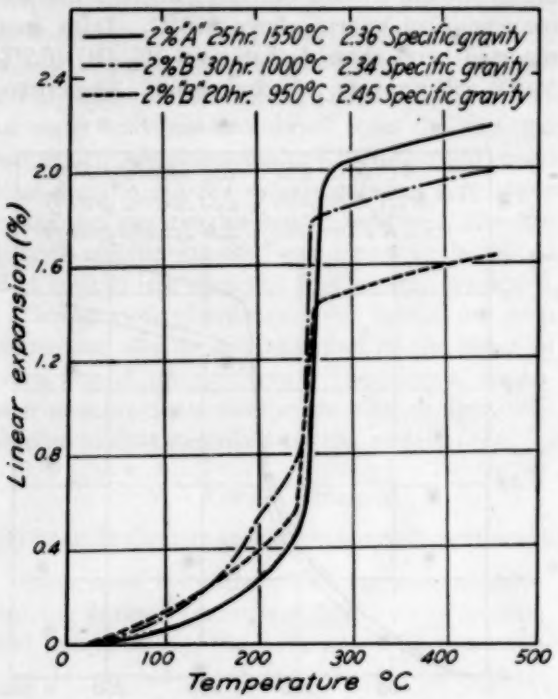

FIG. 3.

silicate. The amount of expansion is much greater than has been reported for cristobalite formed under other conditions. This may be explained by assuming that the cristobalite may be a more consolidated form than normally produced which may have higher expansion. The X-ray data obtained and reported by F. J. Williams on a sample prepared with 2% (A) at 1550°C for 25 hours shows sufficient quartz to account for the specific-gravity difference, *i.e.*, 2.359 instead of 2.333. Excerpts from the report are included in this paper.

VII. Communication Submitted by F. J. Williams[2]

"An X-ray spectrograph was made by the fine powder method using a gas-discharge X-ray tube similar to that of Ksanda,[3] equipped with a copper target and using a camera of 57.65 millimeters diameter. No attempt was made to filter the K-beta doublet from the copper radiation. The

TABLE V

LINE SPECTRUM OF SYNTHETIC CRISTOBALITE. CuK RADIATION

I	(A) 2L (mm.)	I	(B) 2L	I	(C) 2L	I	(D) 2L
2	18.2			1	18.1		
10+	20.8			10	20.4		
10+	22.6			10	22.1		
1	25.8					8	25.4
1	27.2					10	27.4
5	28.8			1	28.5		
				4	28.6		
1	30.1						
5	31.7			5	31.4		
1	32.8			2	32.7		
2	34.7			½	34.7		
8	36.4			9	36.4		
½	38.9	2	39.1	½	38.7		
8	43.5	10	43.6	1	43.0		
				1	43.7		
2	45.2	1	45.4	2	45.1		
3	47.3			3	47.0		
3	48.9			3	48.9		
4	50.5	8	50.8				
1	53.0			½	52.5		
				½	52.9		
2	54.4			2	54.2		
1	55.9					3	55.6
2	57.3			4	57.6		
1	60.5			2	60.9	4	60.8
1	62.2			½	62.3		
				2	62.4		
2	65.7	2	66.1	3	65.6		
1	67.2			1	67.1		
1	68.6			1	68.6	8	68.8
1	70.8			1	70.1		
				½	70.9		
1	73.1			1	73.1		
8	74.2	10	74.6	1	74.5		
1	78.2					3	78.6
1	79.4	2	79.6				
1	81.7			2	81.6		
1	83.3					3	82.6
1	88.2			3	88.6		
8	89.8	8	90.5				
1	93.7			½	94.2		
2	95.2	5	95.8	½	95.6		

(A) Measured film.
(B) Copper (2L calculated).
(C) Cristobalite (calculated).*
(D) Quartz (spectrograph prepared and measured in this laboratory; only lines having an estimated intensity of 3 or greater are included).

* T. F. W. Barth, "Cristobalite Structures, II. Low Cristobalite," *Amer. Jour. Sci.*, **24** [140], 97–110 (1932).

[2] Department of Ceramics, Pennsylvania State College, State College, Pa.

[3] C. J. Ksanda, "A Metal X-ray Tube for Characteristic Radiation," *Rev. Sci. Instruments*, **3** [10], 531–34 (1932).

specimen was mounted on a fine copper wire and the copper lines were used to calibrate the film. The film was measured to 0.1 millimeter and the intensities were estimated. Table V shows these measurements together with the copper, cristobalite, and quartz values.

"A sample of tridymite was prepared by heating the cristobalite in sodium tungstate at 950°C for 120 hours and a spectrograph of the tridymite prepared. There was no obvious fit of the more intense tridymite lines.

"From the spectrograph it would appear that the submitted sample was essentially cristobalite with a small amount of quartz present and no tridymite. An estimate of the amount of quartz from the intensities of the spectrograph lines would be 5 to 10%. The amount calculated from the densities is 9%. If there is tridymite present it is not sufficient to give any lines on the spectrograph, which limits the tridymite to something below 5%. The conversion of the quartz to cristobalite probably started at the surface of the quartz grains in the interface between the quartz and sodium silicate and proceeded inward. Thus any unconverted quartz would be found in the center of the original grain well surrounded by cristobalite. This cristobalite being rather loosely packed would mask the quartz inversion at 575°C and consequently the quartz would not be manifest from the expansion curve."

VIII. Discussion of Williams' Communication

A possible explanation of the conversion at these temperatures is that it is a case of reaction in the solid-liquid state. At the highest temperature employed (1000°C) and at the largest amount of sodium silicate (7%), there was less than 10% liquid present, while at the lower temperature (900°C) with 1% sodium silicate, conversion occurred with less than 1% liquid present. The quartz grains had on their surface a very thin film of sodium silicate due to the method of preparation. This film was adequate to promote the conversion as expressed by the following equation:

$$x\mathrm{SiO_2}\ (\text{quartz}) + \mathrm{Na_2O{\cdot}2SiO_2}\ \left(\begin{matrix}\text{liquid}\\ \text{vapor}\end{matrix}\right) \rightarrow \mathrm{Na_2O{\cdot}}(2+x)\mathrm{SiO_2} \rightarrow \mathrm{Na_2O{\cdot}2SiO_2} + x\mathrm{SiO_2}\ (\text{cristobalite})$$

The sodium silicate would become saturated with respect to silica, and cristobalite would crystallize. The quartz, being the more unstable phase at these temperatures, would be dissolved more readily by the sodium silicate than cristobalite, which would form as the quartz was dissolved.

Further, by a study of the crystal lattices of quartz, cristobalite, and tridymite, the transformation of cristobalite from quartz might possibly be accounted for by one-third of the Si–O bonds being broken, a rotation of the structure 120°, and the Si–O–Si linkage straightened. In a like manner, the transformation of cristobalite to tridymite (cubic to close-packed hexagonal) could be postulated as two-thirds of the bonds being broken and a translation of the two planes of atoms in opposite directions horizontally. In the conversion of quartz into tridymite, a complete rearrangement of the structure might be necessary, although experimental data may later show that this is not the case. The Si–O distances in quartz and cristobalite are nearly identical, being 1.62 and 1.63 Å, respectively. The Si–O distance in tridymite is 1.54 Å, so that a greater amount of energy would be required to bring about the formation of tridymite than cristobalite from quartz.

IX. Conclusions

The investigation established the following facts:

(1) Cristobalite will form in the presence of sodium silicate at a temperature of 890 to 900°C and will form more rapidly the higher the temperature.

(2) The cristobalite formed below 1470°C is in a metastable condition and slowly converts into tridymite.

(3) Cristobalite is formed before tridymite in the conversion of quartz to the higher-temperature forms of silica in a solid-gas or solid-liquid reaction.

(4) Cristobalite formed at 900 to 1000°C has the same index of refraction as that formed at 1500°C, namely, 1.485 to 1.486.

(5) The inversion of low to high form in cristobalite which has been made with sodium silicate as a catalyst occurs at 250 to 260° C.

(6) Time and temperature affect the rate of conversion.

(7) Quartz of finer grain size converts more rapidly than coarser quartz.

(8) The reaction is autocatalytic in character.

(9) The $Na_2O:SiO_2$ ratio of the flux affects the rate of conversion.

(10) The production of 95% cristobalite between 950°C and 1050°C is commercially and economically feasible.

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PROPERTIES OF SOME OHIO RED-FIRING CLAYS*

By A. E. MacGee, W. C. O. White, and T. A. Klinefelter

Abstract

Properties of twenty-six Ohio clays representative of those used in manufacturing heavy ware, such as brick and hollow-ware, were studied from the raw clay to the finished laboratory product. Chemical and petrographic analyses were made. In the raw and plastic states data were obtained on the tempering water, the amount of load necessary to extrude the clay through a die, the base-exchange capacity, and the particle-size distribution as evidenced by sieve analysis and the water-absorption method. In the dry state the minimum drying time, the shrinkage, porosity, apparent specific gravity, dry transverse strength, impact strength, and modulus of elasticity were determined. In the process of heating the clays to 1000°C, observations were made as to the kind and rate of evolution of the gases given off, the endothermic and exothermic reactions, and the expansion characteristics. The softening points of the clays were determined and, after heating to different temperatures, data on shrinkage, absorption, and transverse strength were taken.

I. Introduction

Red-firing clays used in making brick, drain tile, hollow tile, sewer pipe, and similar products are important economically from the standpoint of value and tonnage of ware produced annually. These clays often contain little clay substance, being composed largely of sands, mica, and minerals containing iron, lime, and magnesia. Such minerals in appreciable quantities are objectionable in clays used for the production of white-ware, but for the so-called "heavy ware," high percentages of iron compounds may be desirable for the coloring effect and with the other low-fusing compounds they serve as a flux to produce vitrification at relatively low temperatures. At the same time the heterogeneity of mineral and physical structures introduces difficulties at one or more stages of the manufacturing processes. Some of the clays lack workability, some are difficult to dry safely, and others cause trouble in the initial stages of the kiln firing or in the finish of the firing.

This paper is a study of the composition, structure, and properties of typical red-firing clays under varying conditions incidental to manufacture, from the raw to the finished state. Hence twenty-six red-firing Ohio clays used commercially in the manufacture of heavy ware were selected for the study.

II. Materials and Preparation

Representative samples of clay (1000 to 1500 pounds) were taken at each of twenty-six operating plants. From the geological standpoint the clays were about equally divided in number between alluvial and glacial clays and shales.

The original samples were ground in a 5-foot dry pan, thoroughly mixed, and samples taken for the various tests. Specimens (7 by 1 by 1 inch) were made for the determination of transverse strength and elasticity, full-sized brick for drying experiments, and specimens (2 by 1 by 1 inch) for volume shrinkage, absorption, and impact strength. Ten or more specimens were used for each test.

The samples used for obtaining extrusion pressures through a die and for wet-sieve analysis were made by grinding the clays in a 5-foot dry pan for the first test and by grinding in a pebble mill for 16 hours for the second test.

In preparing samples for determining the amount of material $< 0.7\mu$ by the water-adsorption method, 10 pounds of clay were mixed with 10 gallons of water to which had been added sufficient ammonium hydroxide for maximum deflocculation and the whole was blunged in a pebble mill and allowed to settle. By a series of blungings in the mill and subsequent settlings the coarser material was separated. Finer fractions were separated by the use of the supercentrifuge and the final separation was accomplished with Pasteur-Chamberland filters.

III. Test Methods

The chemical analyses of the clays were made by the method described by Lundell and Hoffman,[1] and the petrographic examination was made in the usual manner.

* Publication approved by the Director of the National Bureau of Standards of the U. S. Dept. of Commerce.
Received August 28, 1934.

[1] G. E. F. Lundell and J. I. Hoffman, "Analysis of Bauxite and Refractories of High Alumina Content," *Bur. Stand. Jour. Research*, **1**, 91 (1928); R.P. 5.

The plastic and dry volume, volume shrinkage, linear drying shrinkage, transverse strength, and elasticity in flexure were determined and the calculations were made according to the American Ceramic Society standards.[2] The impact strength was determined by means of a gravity impact machine.[3] Porosities for the unheated specimens were determined by means of a gas-expansion direct-reading porosimeter[4] and for the heated specimens, by boiling in water 2 hours and immersing 48 hours.

Determinations of the extrusion pressures of the clays in the plastic condition were made with equipment designed by Grunwell,[5] using four different percentages of water for each grind. The clays were extruded through a $^1/_2$-inch orifice by means of a piston (area, 4 square inches) moving at a rate of $^3/_4$ inch per minute.

For determination of particle size, sieve analyses (wet method) were made on samples from both dry-pan and ball-mill grindings. An estimate of the fraction finer than 0.7μ was obtained by a procedure similar to that used in a study of English china clays.[6] A portion of the final fraction collected on the Pasteur-Chamberland filters ($<0.7\mu$ calculated according to Stokes' law) and a sample of the original clay were treated with a normal solution of sodium chloride in order to put them in a more or less uniform condition of cationic adsorption. After washing until chloride-free, the samples were dried and weighed, and the percentage of fine material was calculated according to the formulas[7]:

$$\text{Adsorption (\%)} = \frac{\text{weight loss on drying} \times 100}{\text{dried sample weight}}$$

$$\text{Fine material (\%)} = \frac{\text{adsorption of clay (\%)} \times 100}{\text{adsorption of fine material (\%)}}$$

Base-exchange capacities at $p_H 7$ were determined by electrometric titration of electrodialyzed samples of the original clays. As the original clays contained soluble salts they were leached before dialysis. The cell used was described by Bradfield.[8]

The minimum drying time was considered as that time necessary to dry the specimens without cracking, to the end of the shrinkage period, using the maximum shrinkage rate. These data were obtained by drying full-sized brick in a humidity- and temperature-controlled drier.

The pyrometric cone equivalents (or softening points) were determined according to the American Society for Testing Materials standard method, serial designation C24–33.[9] Three to five tests were made on clays having low pyrometric cone equivalent values (below cone 02). These clays were high in fluxes, and consequently had short vitrification ranges and deformed unexpectedly.

The heating curves of the clays were determined to approximately 1050°C on samples ground to pass a No. 100 sieve and dried at 65 to 70°C.[10] The electric furnace used was heated at a constant temperature rise of about 14°C per minute. The temperature of the sample was obtained by means of a thermocouple embedded in the sample and that of the furnace by means of one at the side of the sample container. Readings were taken at intervals of one minute. The two series of temperature observations were plotted against time and compared, and deviations were interpreted as due to the occurrence of endothermic or exothermic reactions. The work on the evolution of gases from carbonaceous material of the clays[10] was done in a standard combustion train in connection with an electric furnace.

The data on heat-treated specimens were obtained on the clays after having been heated by three methods. The softening point of each of the clays aided in their classification into three groups according to the temperature range in which they would probably vitrify, namely, (*a*) low, (*b*) intermediate, and (*c*) high. The clays were then heated within the respective temperature ranges and trial specimens withdrawn at intervals of one to two cones to establish the most suitable heating range. The tests were duplicated

[2] *Jour. Amer. Ceram. Soc.*, **11** [6], 335–534 (1928).
[3] *Ibid.*, p. 508.
[4] *Ibid.*, p. 499.
[5] P. C. Grunwell, "Studies of Machines for Extruding Clay Columns. Augers, Spacers, and Dies for Brick Machines," *Bur. Stand. Jour. Research*, **1**, 1023 (1928); R.P. 36.
[6] (*a*) T. A. Klinefelter, W. W. Meyer, and E. J. Vachuska, "Some Properties of English China Clays," *Jour. Amer. Ceram. Soc.*, **16** [6], 269 (1933).
(*b*) The determinations on the Ohio clays were made by Joseph W. Gill, Coöperative Fellow, Nat. Bur. Stand. and Eng. Expt. Sta., Ohio State University.
[7] Gile *et al.*, "Estimation of Colloidal Material in Soils," *Dept. of Agric. Bull.*, No. 1193.
[8] R. Bradfield, "A Simplified Cell for Determining the Electrodialyzable Base Content of Soils and Permutites," *Jour. Amer. Soc. Agron.*, **19**, 1015 (1927).
[9] Described in the A.S.T.M. Book of Standards for 1933 Part II.
[10] The determinations of the heating curves and gas evolution of the clays were made by George Machwart, Coöperative Fellow, Nat. Bur. Stand. and Eng. Expt. Sta., Ohio State University.

as a check of the information obtained. As a result of these tests, the clay specimens for physical tests were heated at cones 02 (1095°C), 2 (1135°C), 5 (1180°C), and 8 (1225°C). The time of heating was about 30 hours in each case.

Thermal expansions of three typical clays (No. 2 alluvial clay, No. 10 shale, No. 22 glacial clay) were determined by the interferometer method.[11]

IV. Results

(A) Chemical Composition

The chemical compositions showed high percentages of iron, lime, magnesia, and silica with low alumina when compared to clays of the kaolin type. Sulfur and carbon[12] were not excessive inasmuch as their elimination caused no serious trouble in plants using the clays where slow heating of the kilns allows oxidation to proceed at a safe rate. In the laboratory kilns where the heating rates are comparatively rapid, the black coring and bloating due to incomplete elimination of the carbon and sulfur in some cases was quite noticeable. Carbon in the vegetable form oxidized quite readily, but the bituminous variety required longer time and more care for complete elimination.

The iron content (4 to 9%) accounts for the deep red colors possible on heating and it also assists in forming low-temperature glasses of the iron-lime-silica type.[13]

The lime ranged from 0.1 to about 9%, the magnesia from 0.7 to 4%, the silica from 50 to 75%, and the alumina from about 10 to 20%. Those clays containing above 5 or 6% of lime and magnesia combined showed maximum vitrification at about cone 3 and tended to bloat and deform above this cone. The clays all contained appreciable amounts of soluble salts. In commercial practice some scumming was reported and in a number of cases it was found to such an extent that a barium salt was used as a corrective measure.

(B) Petrographic Examination

(1) Shales

An outstanding characteristic of the eleven shales was the abundance of comparatively large-sized aggregates of very fine-grained particles which were not disintegrated by prolonged washing. In the Dunkard and Bedford shales the aggregates were unusually abundant. The minerals composing the aggregates were largely quartz, sericite, kaolinite, and limonite firmly cemented together. Other common minerals were muscovite, calcite, siderite, rutile, and pyrite. Muscovite was especially abundant in the Dunkard, Bedford, Allegheny, and Conemaugh samples. The Cincinnati shale was unusually rich in calcite still retaining the original fossil shell form. Other minerals present in very small quantities were zircon, hornblende, biotite, and tourmaline.

(2) Alluvial Clays

The grain size of the alluvial clays in general was greater than that of the shales, but the firmly cemented aggregates were not present in any abundance.

A greater variety of minerals was found in the alluvial clays than was observed in the shales. Such minerals as dolomite, zircon, hornblende, garnet, and tourmaline were more common and small quantities of feldspar were found in some of the samples.

(3) Glacial Clays

The grain size of the glacial clays was larger in general than that of either the alluvial clays or the shales. The predominating minerals were the same as those in the alluvial clays and shales, with the exception of muscovite, which was present in very small quantities.

(C) Tests on Clays in the Raw and Heated States

(1) Raw and Plastic Condition

The sieve analyses by the wet method divided the clays into groups based on the relative amounts of material passing through a No. 200 sieve. The alluvial and glacial clays fell into one class, the dry-pan millings showing an average above 90% passing the 200 sieve, while the shales constituted the other group since an average of not quite 60% passed the 200 sieve. With the clays in this state of division (the dry-pan milling corresponds to operating plant practice), the coarse shale aggregates showed consistently lower

[11] C. G. Peters and C. S. Cragoe, *Bur. Stand. Sci. Paper*, No. 393.

[12] George Machwart and J. R. Withrow, "Carbon and Sulphur Content of Ohio Common Clays in Heavy Ware Industries," *Ind. Eng. Chem.*, **22**, 1224 (1930).

[13] This is confirmed by an examination of powders and thin sections of typical clays of the group by G. R. Shelton.

test results in the raw and plastic condition than the alluvial and glacial clays. The shales required about 5% less water for tempering, the base-exchange capacity averaged 4 to 5% less, and the fraction finer than 0.7μ averaged about 8% lower.

After the clays had been subjected to 16 hours' additional grinding in ball mills, the sieve analyses for the alluvial and glacial clays were changed very little, the average amount passing the No. 200 sieve being about 3% more than for the dry-pan milling. A much larger change was shown for the shales, as about 80% of the material passed a No. 200 sieve, or an increase of about 20%.

The effect of breaking down the coarse aggregates of the shales into finer particles is shown in the extrusion pressure tests. With an average of about 21% of moisture the dry-pan millings required a pressure of about 50 pounds per square inch, while the ball-milled samples with the same moisture content would require a pressure of about 175 pounds per square inch. The alluvial and glacial clay samples under similar conditions of moisture content giving 50 pounds per square inch for the dry-pan millings showed an average of 51 pounds per square inch for the ball-milled samples, the increase of one pound being within the experimental error. Figure 1 shows that similar relations held at various other moisture contents where the pressure ranges lay between 25 pounds per square inch and 100 pounds per square inch. Three sets of curves are shown. They are fairly typical for each group and show the difference in tempering water and pressures required. The curves show that increases in moisture content of clays decreased the pressure necessary for extrusion within the limits of the tests.

(2) Dry and Heated States

In the dry state the dry-pan milled samples of the shale group also showed consistently lower test results than the alluvial and glacial clays. The slaking time of the shales was about half that of the alluvial and glacial clays. The dry-volume shrinkage averaged about 8% less, the minimum safe drying time was about half, the transverse strength averaged 100 to 200 pounds per square inch less, and the modulus of elasticity and impact strength were correspondingly less in general.

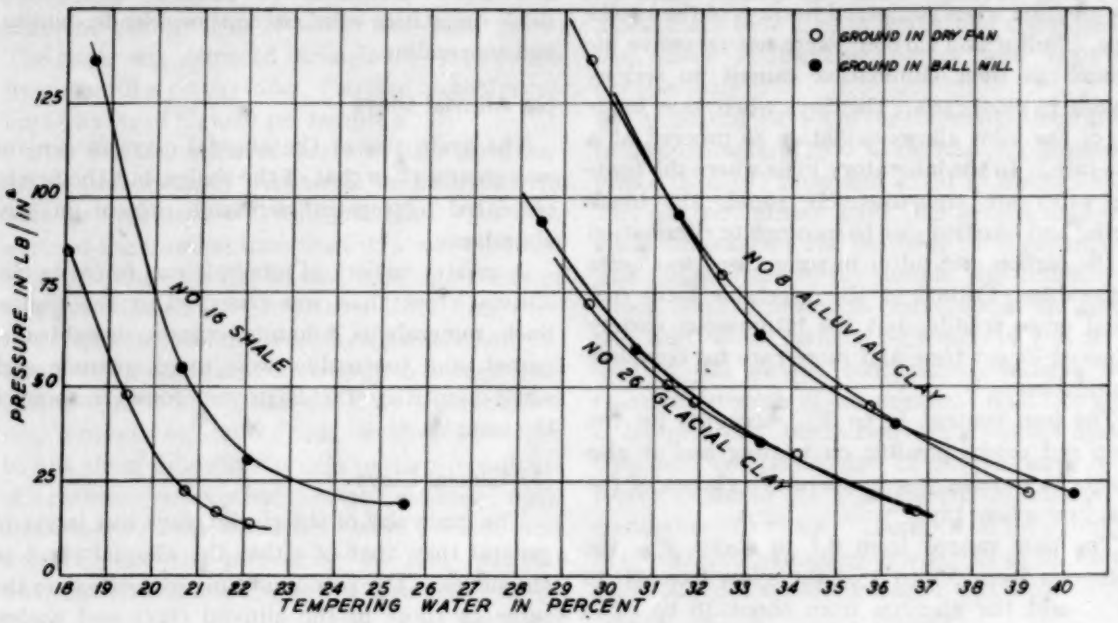

FIG. 1.

Figure 2 shows the general tendencies of properties in the raw and dry states. With increasing base-exchange capacity and fineness of grain there were increases in shrinkage, transverse strength, modulus of elasticity, and impact strength. The various points on the curves are obtained from averages of groups of clays and hence the curves are indicative of general trends only.

(3) During Heating and after Heating

(*a*) *Heating Curves:* Figure 3 shows the endothermic and exothermic reactions obtained as a result of heating four clays: three Ohio clays and for comparison one English china clay which is typical of the kaolin type. All of the clays showed a lag in temperature, according to the thermocouple in the sample, up to 300°C and 400°C, which may be due in large part to expulsion of capillary and hygroscopic moisture. For the English china clay there was a pronounced endothermic reaction between 550°C and 650°C, probably due to breaking down of the clay mineral, and at about 950°C, a rather sharp exothermic reaction. Only one of the Ohio clays showed much evidence of a similar exothermic reaction at this point and it was not so well defined. Five of the Ohio clays, however, showed pronounced exothermic reactions between 300°C and 400°C, the curve for the glacial clay from Findlay, Ohio (clay No. 24), being typical of the five in general. The remaining clays and shales all showed reactions similar to the curves shown for the glacial clay from Toledo (clay No. 22) and the Chagrin shale from Cleveland, Ohio (shale No. 16). There seems to be a more or less continuous temperature lag, or endothermic reaction, of moderate amount from 500 to 900°C for all of the Ohio clays. The usual exothermic reaction at 950°C characteristic of kaolin type clays was lacking, with one exception. It is probable that there is less kaolinite present and more of the montmorillonite type mineral or that an endothermic effect from still other minerals masks the reaction.

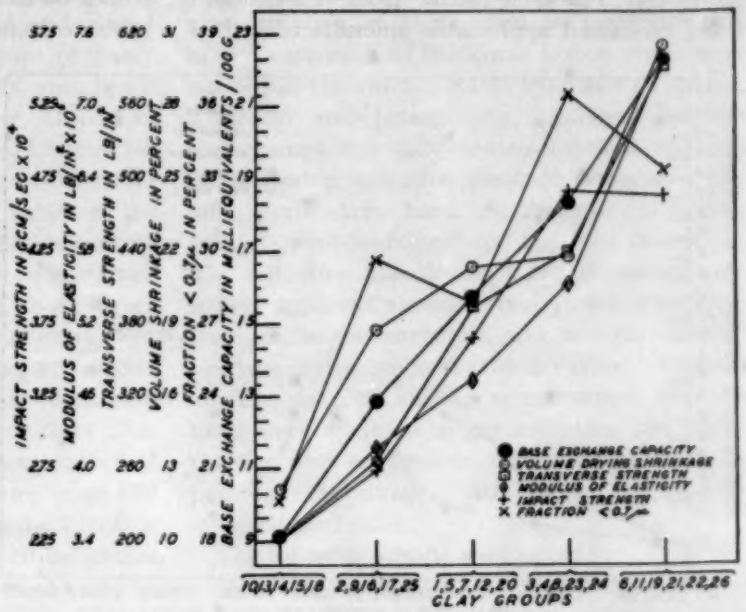

FIG. 2.

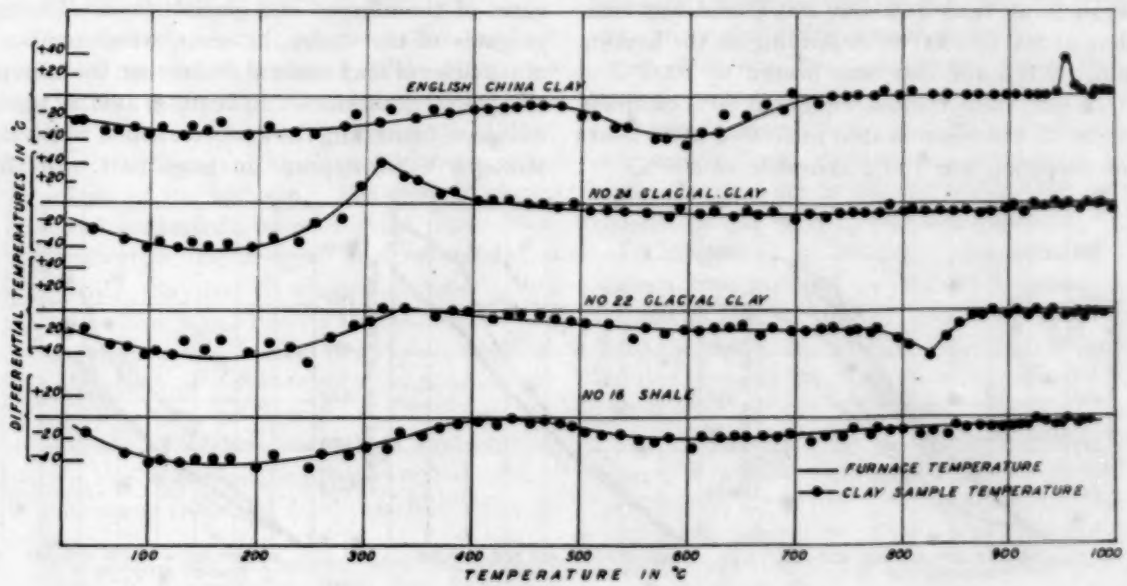

FIG. 3.

(*b*) *Gas Evolution:* In the process of heating clays, gases are given off in the earlier stages up to about 1000°C. Where carbonaceous matter is present, as in the clays under consideration, carbon dioxide forms a portion of the gas evolved. Since the Pottsville shale from Portsmouth, Ohio, contained appreciable amounts of carbon, practically all of which was present as organic carbon, it was selected for the purpose of obtaining data for the evolution of carbon dioxide at heating periods of $1^1/_2$ to 30 hours. The evolution of gas began in all tests at about 200°C and was complete at 800 to 1000°C, depending on the heating rate. When the clay was heated to 1000°C in $1^1/_2$ hours, the evolution was about 80% complete at 800°C, but when heated to 1000°C in 30 hours the evolution was 100% complete at 800°C.

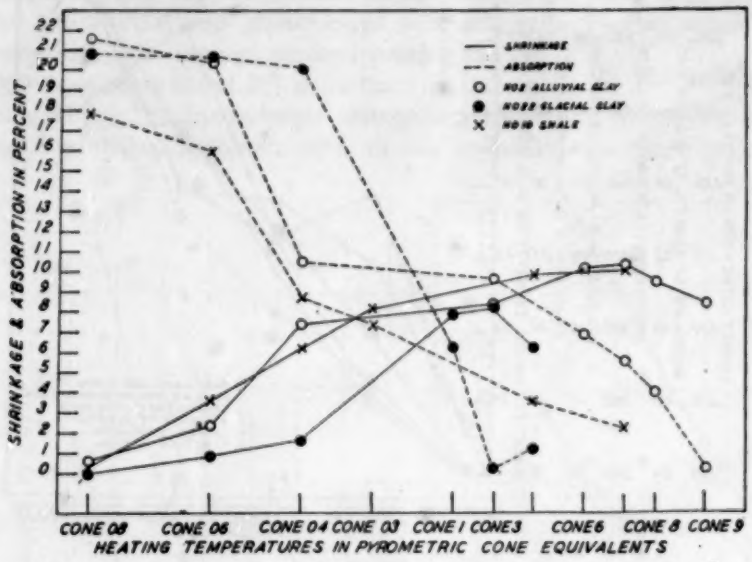

FIG. 4.

(*c*) *Shrinkage and Absorption:* Figure 4 shows the shrinkage and absorption data for the three clays, Nos. 2, 10, and 22. Of the clays studied, Nos. 2 and 10 had the longer ranges (cones 04 to 7) and clay No. 22 one of the shortest ranges (cones 04 to 3). The remaining clays had intermediate heating ranges, and data on shrinkage and absorption for them are therefore omitted. The transition from a highly vitrified state to bloating was in most cases very abrupt, taking place with a temperature increase of about 30°C.

(*d*) *Strength:* The modulus of rupture varied with the heat treatments. The heat treatments range from cones 02 to 5, which in general covers the range of a satisfactorily vitrified product made from these clays. The shales gave a higher strength value at cone 02 than either the alluvial or glacial clays. The alluvial and glacial clays averaged about 2100 pounds per square inch and the shales, 2700 pounds per square inch. The reverse was true in the dry state.

In the dry state, the relatively large-sized aggregates acting as single grains resulted in lower strength values than the finer grains and aggregates of the alluvial and glacial clays. The aggregates of the shales, however, were composed of particles of finer mineral grains than the alluvial and glacial grain sizes. In heating, a glassy liquid develops, furnishing the final bond upon which the strength value depends in large part. In this

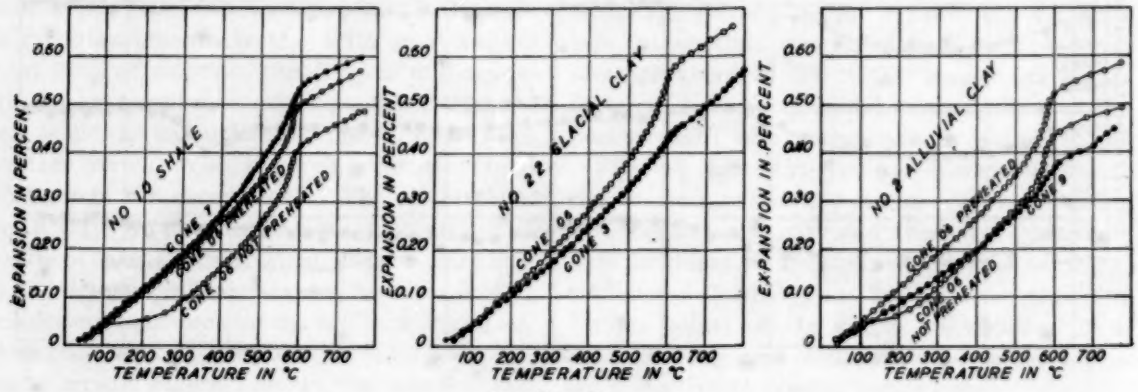

FIG. 5.

case aggregates as such seem to have less effect in the glass development than do the particles from which the aggregate is formed. Since, in general, glasses will form more readily the finer the particle size of the glassmaking components, it follows that the shales, which had intrinsically a finer particle size than the alluvial and glacial clays, would develop a greater amount of glassy bond under a given heat treatment and hence show greater strength. There were, of course, exceptions, such as glacial clay No. 22, but for the group of clays under consideration the shales as a class gave the higher strength values at the heat range around cone 02. In the higher heating ranges of cones 2 and 5, the same tendency was found for the shales as a class to show higher strengths than the alluvial and glacial clays.

(*e*) *Linear Thermal Expansion:* Figure 5 shows linear thermal expansion curves from room temperature to approximately 750°C for clays Nos. 2, 10, and 22. The curves show expansions of samples heated at a low temperature (cone 06) and at a comparatively higher one (cones 7 to 9) in each case. All of the samples showed indication of the quartz inversion from 570 to a' .ut 600°C, it being more pronounced for the cone 06 samples as they contained a greater quantity of free silica than those heated to higher temperatures. The latter showed considerably more glass formation. There was no indication on the curves of the presence of cristobalite. From 400 to 750°C the expansions ranged from 6.8 to 10.3 parts per million.

The effect of moisture sorption after the heat treatment to cone 06 is plainly indicated for clays Nos. 2 and 10 in the curves marked "not preheated." It was necessary to preheat the samples (350 to 400°C overnight) in order to eliminate the effects of the sorption. The cone 06 curves marked "preheated" were plotted from data obtained after the samples had received this treatment. Clay No. 22, which was more vitreous than clays Nos. 2 and 10 after the cone 06 heating, did not show any indication of moisture sorption. The indication of moisture sorption is in accordance with previous findings.[14]

(*f*) *Color:* The clays were all of the red-firing variety, the color depending largely on the amount of iron present and its condition developed by heat treatment, especially at the finish. These colors varied from light salmon to deep reds, and brown to gun-metal shades.

[14] R. F. Geller and A. S. Creamer, "Moisture Expansion of Ceramic Whiteware," *Bur. Stand. Jour. Research*, 9, 291 (1932); R.P. 472.

V. Summary

Samples of twenty-six Ohio red-firing clays, representative of those used in manufacturing heavy ware such as brick and hollow ware, were studied in the various states from raw to heated. Chemical and petrographic analyses, base-exchange capacity, particle-size distribution, tempering water, extrusion pressures through a die, and pyrometric cone equivalents (softening points) were obtained on the raw materials. The minimum safe drying time, shrinkage, porosity, apparent specific gravity, dry transverse strength, impact strength, and modulus of elasticity were determined in the dry state. In heating the clays to various temperatures observations were made as to gas evolution, the endothermic and exothermic reactions, thermal expansion, shrinkage, absorption, transverse strength, and color.

The following results were noted:

(1) The chemical and petrographic analyses showed high percentages of iron, lime and magnesia, and silica, with low alumina, when compared to clays of the kaolinite type. Small amounts of carbon, sulfur, and soluble salts were present. The iron compounds were in sufficient quantity to color all of the clays red on heating. The clays containing relatively large amounts of lime and magnesia had shorter heating ranges than those containing small amounts.

(2) Wet-sieve analyses showed the shales to have a coarser aggregate structure than the alluvial and glacial clays, and tempering water, safe drying time, slaking time, shrinkage, and transverse strength in the dry stage to be correspondingly less for the shales as a class.

(3) Breaking up the grain aggregates of the shales by fine grinding required an increase in the amount of tempering water as well as an increase in the pressure for extrusion. Additional grinding had practically no effect on the alluvial and glacial clays.

(4) The elimination of carbon dioxide in the process of heating was completed between 800°C and 1000°C, depending upon the rate of heating.

(5) Heating curves of the clays indicated the possible presence of the montmorillonite-beidellite type of clay mineral.

(6) The transition from a highly vitrified state to bloating was much sharper than with more refractory clays, taking place with a temperature increase of about 30°C.

(7) Glassy bonds formed at relatively low temperatures and most of the clays showed good strength at heating to cone 02.

(8) All of the clays showed satisfactory strength in the heat range from cones 02 to 5, particularly the shales, which as a class showed consistently higher strengths than the alluvial clays and glacial clays at corresponding heats.

(9) Typical clays from the group showed expansions ranging between 6.8 to 10.3 parts per million in the range of 400 to 750°C, and all showed the usual extra expansion due to quartz inversion at about 575°C when free quartz was present in significant amounts.

Acknowledgment

This investigation was carried out at the Columbus Branch of the National Bureau of Standards, initially under the supervision of S. J. McDowell and later T. A. Klinefelter, superintendent, the latter acting as editor in assembling the data. Wilber Stout, State Geologist of Ohio, advised as to the selection and location of the clays. A. E. MacGee collected the samples and made the earlier tests and W. C. O. White finished the work. The chemical analyses were made by J. F. Klekotka and the petrographic examination by G. R. Shelton.

Portions of the work under the joint supervision of the National Bureau of Standards and the Engineering Experiment Station of the Ohio State University were as follows: the carbon and sulfur determinations and heating curves of the clays were made by G. W. Machwart under the supervision of J. R. Withrow, representing the Engineering Experiment Station. The base-exchange capacity and fine-fraction determinations were made by J. W. Gill under the supervision of A. S. Watts, also representing the Engineering Experiment Station.

CERAMIC ABSTRACTS[1]

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Vol. 14 **May, 1935** **No. 5**

Abrasives

Principles of expanding polishing wheels. Fred B. Jacobs. *Metal Cleaning & Finishing*, **7** [2] 92–94 (1935).—Types of expanding polishing wheels and the particular application of each type are described so that designs to fit requirements may be selected. Illustrated. E.J.V.

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Abrasive wheel. G. H. Bullard. U. S. 1,989,074, Jan. 29, 1935.

Apparatus for producing surfaces of revolution eccentric to one another. A. H. Dall (Cincinnati Grinders, Inc.). U. S. 1,993,831, March 12, 1935.

Art of grinding. G. W. Binns (Cincinnati Grinders, Inc.). U. S. 1,993,823, March 12, 1935.

Bond for abrasive articles. R. C. Benner and G. H. Porter (Carborundum Co.). U. S. 1,993,821, March 12, 1935. An abrasive article comprises abrasive grains and a bond consisting of metastyrol and a plasticizer.

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Detergent abrasive scouring pad. R. B. Kingman (Metal Textile Corp.). U. S. 1,991,559, Feb. 19, 1935.

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[1] The bold-face number following the journal is the volume, the issue number is in brackets, followed by the page numbers, then the year in parentheses.

Abstracts from our abstracter in Czechoslovakia are sent to us through the Czechoslovak Ceramic Society, Praha XIX, 1417.

Art and Archeology

Accuracy and utility of methods of test for mass tone and tinting strength of dry colors. J. W. AYERS. *Proc. A.S.T.M.*, **34** [Part II] 497–520 (1934).—The A.S.T.M. proposed tentative method of test for mass color and tinting strength of dry color pigments or pastes is surveyed. Several changes in apparatus, methods, and materials are recommended. R.A.H.

Art relics of early Mesopotamia. C. BACHE. *Illus. London News*, **185**, 1050–51 (1934).—Discoveries at Tepe Gawra by the joint expedition of the University of Pennsylvania Museum and the Schools of Oriental Research are illustrated. H.H.S.

Chinese collection of George Eumorfopoulos. J. W. TAYLOR. *Sydney Morning Herald*, Feb. 11, 1935.—This collection of 1050 pieces, beginning with the Chou period (1200 B.C. to 250 B.C.), has been acquired by the British nation for £100,000. H.H.S.

Printing on glass, ceramic, and enameled products. L. DUBUIT. *Verre & Silicates Ind.*, **5** [22] 428–30 (1934).—After the glass is etched or engraved, special Dubuit printing machines can be used instead of the powdering process for marking objects. The firing operation is explained. M.V.C.

Raw leadless glazes at low temperatures. C. W. MERRITT. *Bull. Amer. Ceram. Soc.*, **14** [3] 104–106 (1935).

BOOK REVIEW

Rumeileh. Ain Shems Excavations (Palestine). Part III. Biblical and kindred studies No. 5. ELIHU GRANT. Haverford College, Haverford, Pa., 1934. 99 pp., 41 plates, 3 in color. 6 maps. Price $10. The mound Rumeileh contains the ruins of Beth Shemesh, a town which was at the height of its importance between 1500 and 1100 B.C. The first two of these centuries are within the copper age. Iron was introduced about 1300 B.C. Beth Shemesh was in the southernmost chain of Canaanite towns opposing the Hebrew infiltration into Palestine. After the city was conquered it was probably under Philistine rule. This book, "intended to be a transparency for a section of the hill with its contents," may be used without the descriptive publications which have preceded it in the series. It lists the objects found with explanatory maps, drawings, and photographs. GEORGE BRAINERD

PATENTS

Designs for:

Bottle. B. D. FUERST (Owens-Illinois Glass Co.). U. S. 94,824, March 12, 1935. E. W. FUERST (Fleischmann Distilling Corp.). U. S. 94,745, March 5, 1935. E. W. FUERST (Owens-Illinois Glass Co.). U. S. 94,746 and 94,747, March 5, 1935. FRANK MCLAUGHLIN (Carr-Lowrey Glass Co.). U. S. 94,703, Feb. 26, 1935. R. J. MIEDEL (Hazel-Atlas Glass Co.). U. S. 94,618, Feb. 19, 1935. FRASIER SMITH (Hazel-Atlas Glass Co.). U. S. 94,862, March 12, 1935. J. E. SPENCE (Hazel-Atlas Glass Co.). U. S. 94,863 and 94,864, March 12, 1935. N. F. STEUER (Owens-Illinois Glass Co.). U. S. 94,713, Feb. 26, 1935.

Ceiling-type lighting fixture. LURELLE GUILD AND M. E. SURFACE (Chase Cos., Inc.). U. S. 94,686, Feb. 26, 1935.

Container. W. E. GARVEY (Salem Glass Works). U. S. 94,827, March 12, 1935. C. R. UNDERWOOD (Knox Glass Bottle Co.). U. S. 94,641, Feb. 19, 1935.

Glass bottle. L. J. KIHN (J. T. & A. Hamilton Co.). U. S. 94,696, Feb. 26, 1935.

Jar. E. W. FUERST (Owens-Illinois Glass Co.). U. S. 94,672, Feb. 26, 1935. FRASIER SMITH (Hazel-Atlas Glass Co.). U. S. 94,861, March 12, 1935.

Jug. J. S. ALGEO (Hazel-Atlas Glass Co.). U. S. 94,722 and 94,723, March 5, 1935. A. J. CALPHA (Olean Glass Co.). U. S. 94,404, Jan. 29, 1935. B. D. FUERST (Owens-Illinois Glass Co.). U. S. 94,413, Jan. 29, 1935.

Leg for stove, etc. W. F. ROGERS (Crown Stove Works). U. S. 94,711, Feb. 26, 1935.

Method of manufacturing blue glazed ceramic articles. MARGIT BERCHTOLD. U. S. 1,991,918, Feb. 19, 1935.

Cements

Behavior of hardened aluminous cement on heating. W. CZERNIN. *Tonind.-Ztg.*, **58** [84] 1022 (1934).—Dicalcium hydroaluminate forms hexagonal plates on dehydration. This compound does not change its crystalline form even with complete dehydration (about 400°) which proceeds uniformly and continuously. Reactions occurring in Portland cement on hydration are discussed. M.V.C.

Cements standards. ANON. *Tonind.-Ztg.*, **58** [100] 1222–24 (1934).—New Brazilian and Czechoslovakian standard specifications for cements are discussed. M.V.C.

Fused cement. R. PETTENATI. *Industria chimica*, No. 11, p. 1484 (1934); abstracted in *Verre & Silicates Ind.*, **6** [1] 11 (1935).—Fused cements have the following advantages over Portland cement: (1) good initial resistance (500 kg./sq. cm. after 12 hr.), (2) considerable resistance to corrosive chemical waters, (3) setting during freezing, (4) rapid setting, (5) permanent volume, and (6) possibility of storing. Bauxite and lime are the raw materials and the best qualities are obtained in an electric furnace. The characteristics of a Finnish fused cement are given. M.V.C.

Hardening and corrosion of cement. VIII. K. E. DORSCH. *Cement & Cement Manuf.*, **7** [2] 45–53 (1934).—D. discusses effects of (1) corrosion temperature of salt solutions, (2) surface area and quantity of test pieces on attack by salt solutions, (3) preliminary storage on the resistance of cement to chemical attack. G.R.S.

Portland cement clinker minerals and their formation. LENNART FORSEN. *Angew. Chem.*, **47**, 162–63 (1934); for abstract see *Ceram. Abs.*, **13** [7] 170 (1934). (*C.A.*)

Rapid set of alumina cements caused by admixtures.

D. STEINER. *Stavivo*, p. 21 (1934).—There is only a gradual difference between fused and clinkered alumina cements. The fused cement sets faster, which may be explained by the higher firing temperature and the lower lime content. Non-fused alumina cement may be mixed with 8% fused cement and with only 4% Portland cement. By these additions the set is accelerated by the interaction between the free lime in Portland cement and the calcium mono-aluminate. The set of alumina cements is accelerated essentially by the addition of 0.1% hydrated lime; mixtures with 0.5% are of very rapid set and with 1.0% the mixes are worthless. The same effect is caused by trass (the experiments were made with the Czechoslovakian trass from Hodojevo) and by gypsum, but no satisfactory explanation can be offered for these phenomena. R.B.

Special cements. W. CZERNIN. *Tonind.-Ztg.*, **58** [102–103] 1245–46 (1934).—The effect of tricalcium aluminate in Portland cement is discussed on the basis of the latest investigations. Bibliography. M.V.C.

PATENT

Gypsum plaster. G. D. KING (U. S. Gypsum Co.). U. S. 1,989,641, Jan. 29, 1935. Gypsum plaster whose setting time is stabilized against disturbance by adventitious admixture of accelerating and retarding influences comprises calcined calcium sulfate as the setting ingredient and about 3% or less of a set-stabilizing composition which latter comprises a retarder, lime, and an acid-reacting soluble sulfate from the group consisting of aluminum, potassium, nickel, and ferric iron.

Enamels

Acid-stable enamels. A. BRUINS. *Emaillerie*, **1** [11] 5–7; [12] 5–9 (1934); abstracted in *Emailwaren-Ind.*, **12** [1] 6 (1935).—The silica content should be from 60 to 68%. A higher addition of soda or a corresponding amount of water-glass should be used to equalize the coefficient of expansion. Opacification usually produces difficulties. Alum or aluminates with an addition of some sulfuric acid are used as electrolytes. No satisfactory substitute for clay was found. Acid-stability is determined with 7% citric acid after treating the enamel for 20 hr. It is determined quantitatively through a loss in weight or by determining the extent of dissolving. The latest German researches on the subject are dealt with. M.V.C.

Acid-stable enamels. L. VIELHABER. *Emailwaren-Ind.*, **11** [49] 401–404 (1934).—Difficulties in producing and testing acid-stable enamels are given and several acid-stable enamel batches are discussed. M.V.C.

Adherence in sheet-iron enamelware. ADOLF DIETZEL. *Sprechsaal*, **68** [1] 3–6; [2] 20–23; [3] 34–36; [4] 53–56; [5] 67–69; [6] 84–85 (1935).—The firing process was carefully studied on a series of sheet-iron ground enamels of a composition similar to the ground, but having different additions of adhering oxides. It was found that materials known as "adhering oxides" do not react in the same way or produce the same adhesion to the iron. The adhering oxides were classified into (1) poor adhering oxides, such as Fe, Cr, Ce, Ti, V, U, and Nb, (2) average adhering oxides, such as MnO_2, nitrates, and nitrites, and (3) good adhering oxides, to which belong the technically important CoO and NiO. The important reactions occurring in enamels containing adhering oxides were studied. The reactions in which the adhering oxides do not participate are (*a*) Fe + O from the air ⟶ hammer scale (FeO + Fe_3O_4); (*b*) the hammer scale is dissolved by the softened or molten enamel; (*c*) Fe_3O_4 (from the hammer scale) + Fe ⟶ 4Fe; (*d*) FeO + diffused oxygen from the air ⟶ Fe_2O_3, FeO + Fe_2O_3 ⇄ Fe_3O_4, oversaturation in Fe_3O_4 and separation of magnetite; (*e*) Fe_3O_4 + O ⟶ Fe_2O_3, oversaturation in Fe_2O_3, and separation of hematite. The degree of firing at which the reactions *a*, *b*, and *c* occur was designated as A; the enamel is usually colored green. Reaction *d* takes place in firing stage B; the enamel is black (overfired). In firing stage C the enamel gets "copperheads"; it has a reddish glittering appearance because of the separation of hematite (*e*). The adhering oxides always react in firing stage A (FeO-stage) as follows: Poor adhering oxides form compounds with the ferrous oxide originated, *e.g.*, $FeO{\cdot}Cr_2O_3$, $FeO{\cdot}V_2O_3$, and probably also solid solutions. These oxide layers adhere to the iron in a manner similar to hammer scale. The enamel becomes attached to these crystals and also adheres to the iron. The adherence is unsatisfactory and is insufficient for practical purposes. The average or medium adhering oxides or oxidation agents promote the formation of the "second hammer scale coat" in firing stage B, according to reaction *d*, and promote a certain adherence whose effect is also poor. The good and technically important adhering oxides are reduced by iron into the elements Fe + CoO(NiO) ⟶ FeO + Co(Ni). Because of the precipitation of these metals on the iron, local currents appear which produce a strong corrosion of the iron surface at high temperature. The enamel gets into the cavities and adheres. A second reaction, 2Fe + CoO(NiO) ⟶ FeO + Co(Ni), takes place. The cobalt or nickel precipitated is distributed in the melt in the form of small particles; these do not play an important rôle in the adherence. These 2 reactions, fundamental for the technical process of adherence, were exactly determined microscopically, analytically, electrochemically, and thermodynamically. On the basis of these studies, the adherence of decorating enamel and the manner of obtaining the practically important white ground are discussed. During the electrochemical investigation, it was found that a kind of oxyhydrogen "chain" may be produced in enamel melts at 900°, a fundamental fact for the question of the diffusion of gases in silicates. See also *Ceram. Abs.*, **13** [11] 284 (1934); **14** [1] 3 (1935). M.V.C.

Antimony compounds in enamel. L. VIELHABER. *Emailwaren-Ind.*, **11** [46] 380–81 (1934).—The poisonous effect of antimony in enamels is discussed. Pentavalent antimony is not poisonous, especially when it is added to the mill. M.V.C.

Barium and zinc oxides in enamel. K. KAMP. *Glas-*

hütte, **64** [44] 715–17 (1934).—Various enamel batches are analyzed and the effect of zinc oxide on the enamel is discussed. It was found that zinc oxide is an excellent flux for powder enamel; it promotes the formation of enamel and has a favorable effect on its chemical resistance, but it has no opacifying effect. Zinc oxide may be replaced advantageously by barium oxide (introduced as barium carbonate) in the enamel batch. Because of its greater molecular weight, BaO raises the refractive index of the enamel, and hence its luster. Calculations showing how to replace ZnO by $BaCO_3$ are given. BaO may also replace lead in majolica enamel to a great extent. M.V.C.

Causes of defects in enameling. KUBE. *Emailwaren-Ind.*, **11** [43] 353–56 (1934).—The selection of raw materials, their preparation, mixing, firing, grinding, and application of the enamel are briefly discussed. M.V.C.

Coating enamels free from borax. L. VIELHABER. *Emailwaren-Ind.*, **11** [43] 356–57 (1934).—Several coating enamels free from borax are analyzed. These enamels are more resistant to chemical attack, but have a much higher coefficient of expansion than coating enamels containing borax. The fact that such a coat enamel would be adapted to the ground enamel with regard to its fusibility and coefficient of expansion is important. M.V.C.

Comparative experiments with zinc oxide. L. VIELHABER. *Emailwaren-Ind.*, **11** [50] 409–10 (1934).—Zinc oxide is not used in enameled ware for eating, drinking, or boiling because of its poisonous effect. It does not opacify the enamel but is used for its fluxing effect. It does not affect the expansion of the enamel as other fluxes, such as soda or potassium salts. Experiments with two enamel batches containing various kinds of zinc oxide are discussed. The color and appearance of the enamel depends on the kind of zinc oxide used. M.V.C.

Defects in enameling, their cause and elimination. ANON. *Emailletech. Monats-Blätter*, **10** [2] 20; [3] 32; [5] 56–57; [6] 69; [7] 81; [8] 91; [9] 99; [10] 107; [12] 123 (1934). M.V.C.

Drying of refrigerator finishes. C. F. MAYER. *Ind. Heating*, pp. 135–37 (Nov., 1934).—The treatment of the metal before vitreous enamel is fired on at about 1600°F and types of furnaces used in quantity production are described. M.H.

Enamel from enamel. L. VIELHABER. *Emailwaren-Ind.*, **11** [51] 419–20 (1934).—Attempts to use waste enamel in the production of ground enamel for sheet iron are discussed. M.V.C.

Enameling clay researches. L. VIELHABER. *Emailwaren-Ind.*, **11** [52] 426–27 (1934).—V. discusses the experiments of McIntyre ("Recent—" *Ceram. Abs.*, **14** [3] 63 (1935)). M.V.C.

Enameling iron. N. H. OAKLEY-EVANS. Presented before Inst. of Vitreous Enamels. *Metallurgia*, **11** [61] 13–14 (1934); *Metal Cleaning & Finishing*, **6** [12] 634 (1934).—The characteristics of a special grade of iron to meet the needs of the enameling industry include cleanliness of the surface and structure, freedom from distortion, a surface possessing bonding quality, uniformity and consistency in quality, accuracy in gage, size, and flatness, reliable welding properties, and deep drawing qualities. "Copper-heading" is caused by the local oxidation of the metal so that excess iron oxide is produced. Cleanliness of the metal surface, enamel firing procedure, and expansion range of the enamel affect the strength of attachment of the enamel and therefore the defect known as "fishscaling." E.J.V.

Experiments on cast-iron enamel. W. OBST. *Emailwaren-Ind.*, **11** [42] 346–47 (1934).—It was found that an increase of the SiO_2 content in enamel lowers its coefficient of expansion, increasing the feldspar content slightly augments it, borax increases it, and iron oxide has no marked effect on it. Quartz raises the softening temperature and borax lowers it, while feldspar does not affect it. Fishscales were observed in enamels containing red iron oxide as addition to the mill; mill additions of metallic aluminum and black and red iron oxide decrease the adhering strength of the enamels. A brief review of the researches of Kräutle, Krebs, Poste, and Vielhaber on the composition of cast iron is given. M.V.C.

Feldspar. L. VIELHABER. *Emailwaren-Ind.*, **11** [47] 387–89 (1934).—Phonolite, pumice stone, and other minerals containing silica, alumina, and alkalis can be used successfully in the production of colored and ground enamel instead of feldspar. The composition of Scandinavian and German feldspars is given. See also *Ceram. Abs.*, **14** [1] 20 (1935). M.V.C.

Fish eyes. L. VIELHABER. *Emailwaren-Ind.*, **11** [48] 394–95 (1934).—Fish eyes represent light-colored cavities or depressions of pea or hazelnut size in majolica enamels. They are due to local concentrations of sulfur on the iron surface, therefore the sulfur content of the iron should be as low as possible. Other ways to avoid the appearance of fish eyes are to subject the iron to a severe calcining and to fire the ground more sharply. M.V.C.

Glass as a carrier of boric acid. L. VIELHABER. *Emailwaren-Ind.*, **11** [48] 393–94 (1934).—Although glass is a raw material which can be used in the manufacture of enamel, its use presents great difficulties because of its varied composition, content of undesirable components, and high fusing temperature. M.V.C.

Grinding and preparation of enamels. WILLIAM J. BALDWIN. *Ceram. Forum*, **1** [4] 2 (1934); abstracted in *Metal Cleaning & Finishing*, **7** [2] 91 (1935).—Fine grinding, especially in colored enamels, gives a truer color and one that is less likely to be mottled. It aids in the suspension of the enamel, gives the enamel more of a set, and divides and disseminates the opacifier more evenly throughout the enamel. There are limits of grinding for each type of ware. Many so-called imperfections caused by the enamel may be traced to the manner in which it is ground and prepared for use. E.J.V.

Ground enamels without borax. L. VIELHABER. *Emailwaren-Ind.*, **11** [42] 345–46 (1934).—Several ground enamels free from borax are analyzed. These batches require higher firing temperatures and have higher coefficients of expansion but are much more resistant to the attack of acids. M.V.C.

Heat technical investigations of semigas firing. A. JAESCHKE. *Glashütte*, **64** [39] 643–45; [40] 661–63 (1934).—Details of heat technical studies performed on a muffle kiln used for firing sheet-iron ground enamel are given. M.V.C.

Influence of impurities in iron on the impact resistance. G. SCHMIDT. *Arch. Eisenhüttenwesen*, **8**, 263–67 (1934).—Starting from pure Armco iron specially treated for this

purpose, various amounts of C, P, S, O, and N were added and the impact resistance was determined. The steep decline of the impact resistance-temperature curve shifts with an increasing amount of impurities toward higher temperatures, and the maximum impact resistance shifts toward lower temperatures. N was found to exert the greatest influence and S the least, O and P showing intermediate values. O and S seem to be of importance in the mechanical aging of steel, whereas small amounts of C, S, and P show no influence. W.M.C.

Materials and products used in producing enamel. ANON. *Céram., Verrerie, Émail.*, p. 21 (1933); abstracted in *Rev. belge ind. verrières*, **4** [7] 160 (1933).—B_2O_3 exerts a favorable action on the elasticity and firing range of enamels, aids in preventing crystallization, and lowers the firing temperature as well as the chemical resistance of the enamel. M.V.C.

Micro-gas analysis of gas trapped in vitreous enamels of enameling iron during firing. S. E. FREEMAN AND V. W. MELOCHE. *Jour. Amer. Ceram. Soc.*, **18** [4] 123–25 (1935).

Raw materials. L. VIELHABER. *Emailwaren-Ind.*, **11** [51] 417–19 (1934).—The waste in the use of raw materials during their working and fusing and in the enamel when coating is discussed, and methods for lowering this waste are dealt with. M.V.C.

Repairing defects in enameled ware. J. NAPPÉE. *Verre & Silicates Ind.*, **6** [1] 6–7 (1935).—Defective enameled ware need not be discarded by manufacturers, for small defects in enameled ware can be quickly and simply repaired. Tools and methods of procedure are given. M.V.C.

Rust in cast-iron pieces. L. VIELHABER. *Emailwaren-Ind.*, **11** [46] 381 (1934).—Rust on cast iron is caused by (1) the cast-iron piece remaining too long a time in the mold, and (2) the molding sand being too moist, frozen, or unsuitable. Moisture from the sand penetrates into the pores. Cast iron should not contain more than 0.1 sulfur because the iron sulfide or manganese sulfide present on the surface disintegrates and forms an acid which attacks the cast iron. The molding sand should possess a high gas permeability, low iron content, and low moisture. M.V.C.

Titanium compounds and their application in vitreous enamels. C. J. KINZIE AND J. A. PLUNKETT. *Jour. Amer. Ceram. Soc.*, **18** [4] 117–22 (1935).

Water-cooled enamel containers. L. VIELHABER. *Emailwaren-Ind.*, **11** [42] 347 (1934).—The effect of temperature and consistency of the enamel on its coating power is discussed. The researches of Gilbert (*Ceram. Abs.*, **14** [1] 6 (1935)) are briefly reviewed. M.V.C.

White ground enamel for sheet iron. L. VIELHABER. *Emailwaren-Ind.*, **11** [47] 385–87 (1934).—V. discusses the researches of J. D. Tetrick (*Ceram. Abs.*, **14** [1] 6 (1935)). M.V.C.

BOOK

Research department of the Gutehoffnungshütte-Konzerns. Vol. 3, No. 1, April, 1934. VDI-Verlag, Berlin. Price 3.15 Rm. Reviewed in *Sprechsaal*, **67** [34] 520 (1934).—The report dealing with "Enameled cast iron and its testing," by Bademacher discusses the properties of majolica enamels containing lead used for enameling ovens, their testing, thermal stability, impact strength, and resistance to sudden changes of temperature. M.V.K.

PATENTS

Production of enameled articles carrying gloss and mat finish. RICHARD TÜRK (Porcelain Enamel & Mfg. Co.). U. S. 1,993,196, March 5, 1935.

Tile construction. C. G. DUFFY (Sealed Joint Products Co., Inc.). U. S. 1,991,550, Feb. 19, 1935. H. P. C. KEULS (Sealed Joint Products Co., Inc.). U. S. 1,991,558, Feb. 19, 1935.

Glass

Breaking strength of glass. A. J. HOLLAND AND W. E. S. TURNER. *Jour. Soc. Glass Tech.*, **18**, 225–51 (1934).—Determinations of modulus of rupture were made on 2300 specimens cut with a diamond under constant load from 26-oz. drawn sheet glass of the composition SiO_2 72.22, Al_2O_3 + Fe_2O_3 1.92, CaO 8.84, MgO 2.89, Na_2O 13.6%. The dimensions were as follows: length 10 cm. (effective length between knife edges 7.6 cm.), width 0.6 to 1.5 cm., and thickness 0.25 to 0.31. The modulus of rupture varied with (1) position of the diamond-cut edge according to whether it was in tension or compression, (2) state of annealing or reannealing, (3) interval of time after reannealing (3 days' interval was adopted for practical purposes), (4) width of the specimen, and (5) condition of the edges: (*a*) cut with the diamond, (*b*) sealed by edge-melting, (*c*) ground and mechanically polished, (*d*) ground and mechanically polished, followed by fire-finishing. A summary of important data obtained is tabulated. Specimens tested with the diamond-cut edge in compression gave values of the same order as those with fire-finished edges and much greater than those with cut edges in tension or edges mechanically ground and polished. The last-named types always gave the more consistent results. Three types of fracture, straight, V, and ½V shape, were found, depending on width and on edge condition. Straight fractures were regularly obtained with specimens less than 0.9 cm. wide, with cut edges or ground and polished edges. Specimens with fire-polished edges always gave a large proportion of V and ½V fractures whatever the width tested.

No. of specimens tested	Modulus of rupture, weighted mean (kg./cm.²)	Coefficient of variation	Width of specimens (cm.)	Conditions of test (generally tested 3 days after reannealing unless otherwise stated)
27	603	7.2	0.6 –0.7	Diamond-cut edges in tension
56	534	7.2	1.0 –1.1	
22	498	8.0	1.3 –1.4	
125	903	22.7	0.89–1.14	Diamond-cut edges in compression
200	1023	18.8	0.75–0.85	Fire polishing the cut edges in tension
100	1008	14.5	0.75–0.85	Fire polishing the cut edges in compression
125	572	12.2	0.89–0.93	Mechanically ground and polished edges, not reannealed
100	946	17.1	1.0 –1.05	Mechanically ground and polished edges, fire polished and reannealed
100	1123	15.5	0.8	

See also "Measurements—," *Ceram. Abs.*, **14** [2] 35 (1935). A.A.

Carbon or sulfur yellow and selenium red glasses. II. LUDWIG SPRINGER. *Glashütte*, **64** [46] 756–57 (1934).—Four color tones may appear with selenium. With a neutral and partly oxidized atmosphere, rose-colored glasses are obtained which turn into brown when transferred into a reducing air. Elementary Se yields a pink glass only in oxidizing and neutral atmospheres, and the glasses are colored more deeply than when selenite of soda is used. To obtain rose glasses, a mildly oxidizing atmosphere is necessary, and the use of saltpeter and arsenic is recommended. Potash glasses have a purer rose color than soda glasses. The pink color depends on the presence of elementary Se; when oxidized too strongly, the glass loses its color because of the oxidation of selenious salts. The brown coloring appearing in reduced firing is due to the formation of multiple selenides, while achromatism is due to the formation of alkaline selenites. S. recommends that the atmosphere be always weakly oxidizing when melting, working, and cooling the glass. The purest sands contain carbon which affects the Se coloring or decolorizing; hence it is necessary to calcine them or to add some saltpeter or arsenic to the batch. For Part I see *Ceram. Abs.*, **14** [1] 7 (1935). M.V.C.

Chilled plate glass. V. Bending strength, Young's modulus, and stress-strain relation of the glass. T. ARAKI, S. TAKAHASHI, AND S. MORI. *Jour. Soc. Chem. Ind.* [Japan], **37** [12] 737*B* (1934).—Data on the bending strength and elasticity of chilled plate glass are given. For Parts III–IV see *Ceram. Abs.*, **14** [3] 64–65 (1935). M.V.C.

Corhart cast blocks in the glass industry. VLADIMÍR ŠKOLA. *Sklarske Rozhledy*, p. 123 (1933); *Stavivo*, p. 185 (1934).—Illustrated. R.B.

Corning Glass Works. ANON. *Ceram. Ind.*, **24** [3] 166–69 (1935). E.J.V.

Course in glassmaking. R. D. *Verre & Silicates Ind.*, **5** [22] 425–27; [24] 467–69 (1934); **6** [2] 27–29 (1935).—The automatic manufacture of bottles with the Owens machine and the operation of the feeder of W. M. J. Miller are explained. Notes on the composition and properties of hollow glassware are given. See also *Ceram. Abs.*, **14** [3] 65 (1935). M.V.C.

Czechoslovakian laboratory glassware compared with foreign products. *Rept. Glass Inst.* [Hradec Králové]; *Sklarske Rozhledy*, p. 81 (1934).—The Kavalier chemical glass "S" is highly resistant to alkali and concentrated sulfuric acid, and the Kavalier borosilicate glass "Palex" in addition is highly resistant to distilled water and hydrochloric acid. The product of best chemical resistance is the Kavalier glass "Neutral." The Reich glasses "Eserco" and "R-normal" have a high resistance to distilled water and ammonium phosphate solutions and their resistance against alkalis is not lower than that of the Jena glass "20." It was proved by a series of tests that the Czechoslovakian laboratory glasses are equal to the Jena glasses. R.B.

Decoloration of soda-lime-silica glass to produce white hollow glass. HUGO KÜHL. *Glashütte*, **64** [45] 731–32 (1934).—Pyrolusite and selenium can be used under certain conditions to decolorize soda-lime-silica glasses which are to be worked into white hollow glass. Selenium decoloration gives the purest "white" but is more expensive. The melting of the ground glass requires great care because it greatly affects the decoloration when using selenium or pyrolusite. Among the combined decolorizers, a mixture of selenite of soda with cobalt oxide gave good results. Details are given. M.V.C.

Effect of chemical composition on the brown coloring of glass by sulfur. K. LITZOW AND G. BROCKS. *Sprechsaal*, **68** [4] 51–53 (1935).—Melting experiments made at the Silesian Technical Glass School are reported. The favorable effect of additions of sulfate and charcoal on the brown coloring of glasses and their effect on systematically changed glasses were studied. The effect of separate glass formers is given in the following series: Na_2O, K_2O, BaO, SrO, CaO, MgO, B_2O_3, CdO, and ZnO. The order of succession from Na_2O to ZnO shows increasingly lighter colors. M.V.C.

Effect of radium on glass. P. P. LASAREFF. *Keram. i Steklo*, No. 4, pp. 285–86 (1928); translated into German in *Glashütte*, **64** [44] 721–22 (1934).—The researches of Doelter (Radium and Colors, pp. 48–53, 1910, Dresden) and of Ramsay on the effect of radium on glasses of various composition and the observations of L. on the coloring of colorless borax glass from the effect of radium are discussed. Dark brown-black spots were observed on the glass after 24 hr. exposure to radium. These spots do not form thin layers on the surface, but penetrate deeply into the interior of the glass; this fact shows that the coloring is produced by β-rays, while α- and γ-rays are filtered off through the glass surface. This color disappears with time. Borax crystals are not colored by the rays, and as the glass contained small crystallization centers on the surface, these were not colored; but borax glass itself becomes violet-brown after 24 hr. of exposure. M.V.C.

Effect of "soft" X-rays on glass. JAROSLAV CHALOUPEK. *Sklarske Rozhledy*, p. 123 (1933).—Some glasses are darkened by the action of X-rays of high wave-lengths (soft rays). R.B.

English design in glassware. JAMES H. HOGAN. Presented at meeting of Roy. Soc. Arts, Jan., 1935. *Pottery Gaz.*, **60** [693] 376–77 (1935).—An English style of glassware once existed but was lost. A typical style should be evolved and preserved. E.J.V.

Experimental melts of fused silica disks. M. A. BESBORODOV AND V. P. PRIANISHNIKOV. *Jour. Opt. Mech. Ind.* [U.S.S.R.], **7**, 3 (1934).—Disks of a small diameter were prepared in a high-frequency laboratory furnace excited from a motor generator. The resistance and ash-content of the graphite crucibles increased with the duration of their service. The loss in silica during the experimental melts with applied vacuum increased with the duration of the melt. It was 5 to 10% for 60 to 70 min. and reached 26 to 30% for 2 to 2½ hr. (*J.S.G.T.*)

Firing with heavy kerosene oil in the glass industry. J. ARNOUL DE GREY. *Chaleur & ind.*, **15** [169] 967–81 (1934); abstracted in *Verre & Silicates Ind.*, **5** [20] 391 (1934).—A detailed discussion is given of (1) thermal data of the glass industry and melting principles of various kinds of glass, (2) special reasons for using heavy oil as fuel in the glass industry, (3) results obtained, and (4) characteristics of heavy oil. A. concludes that because this kind of fuel is

extensively used for firing small tank furnaces, feeders, and annealing furnaces, there is no technical reason for not using it for large tank and pot furnaces. M.V.C.

Glass bottle machinery. II. W. A. MOORSHEAD. *Mech. World*, **97** [2509] 107–108 (1935).—Machines are needed which will make a range of articles at one time and will operate with multiple molds. The temperature at which the glass is gathered must be controlled. Redesigning of the machines to make 2 or 3 articles in one mold has increased production per machine. The quality of the ware has improved as the machine speeds are slower. Means of maintaining a flow of glass in the forehearths must be developed for efficient operation, and a control of the gob size must be allowed for. Various types of flow machines are described. Illustrated. For Part I see *Ceram. Abs.*, **14** [4] 90 (1935). E.J.V.

Glass painting of Hans Baldung Grien. CHARLOTTE STEINBRUCKER. *Sprechsaal*, **68** [3] 43 (1935).—A brief review is given of glass paintings of this well-known master of the 16th Century. M.V.C.

Glass for sculptures. R. BARTA. *Sklarske Rozhledy*, p. 21 (1934).—Cast glass of high resistance to temperature changes, *i.e.*, Pyrex-brand glass, may be used for sculptures. R.B.

Glasses for low-voltage insulators on high-frequency communication lines. E. I. AVRAMENCO. *Keram. i Steklo*, **10** [12] 29–31 (1934).—A. discusses the effect of the chemical composition of glass on its dielectric losses. Tables showing the results of measurements made on glasses of various compositions are given. M.V.C.

Grinding a big mirror. W. KAEMPFFERT. *New York Times; Science*, p. 18 (March 3, 1935).—An account of the delicate and difficult task of grinding the dish-shaped mirror for the McDonald Observatory is given. M.V.C.

Grinding glass. A. SALMONY. *Sklarske Rozhledy*, **10**, 42–43 (1934); abstracted in *Chem. Zentr.*, **ii**, 653 (1934).—Processes during the chemical grinding of glass are discussed. M.V.C.

Ground feldspar in the glass industry. WILHELM SCHMIDT. *Glashütte*, **64** [39] 645–47 (1934). M.V.C.

Microscopic examinations of frosted lamp bulbs. A. SALMONY. *Sklarske Rozhledy*, p. 121 (1933).—Fluoric acid forms hollow crystals which protect the glass of the bulb. R.B.

Physical and chemical reactions on the surface of glass. A. SALMONY. *Sklarske Rozhledy*, p. 18 (1934).—The higher its content of acid constituents the higher is the absorption of gases by the glass surface. Absorption of water and swelling of the surface precede the devitrification of surfaces of glass rich in alkalis. R.B.

Polymerization products as intermediate layers for safety glass. A. BRESSER. *Synthetic & Applied Finishes* [London], **5** [49] 16–20 (1934); abstracted in *Sprechsaal*, **67** [26] 392 (1934).—Materials such as the ester of acrylic, crotonic, and cinnamic acids can be compared to Kinon glass with regard to their durability; they are superior in other respects. Polymerized ethyl acrylate and the non-polymerized compound (it must be subsequently polymerized) can be used in safety-glass production. These intermediate layers are weather-stable, are not attacked by water or oil, and are stable to most organic solvents. Such safety glasses are far superior to celluloid glass. Details are given. See also *Ceram. Abs.*, **12** [7] 258 (1933); **14** [3] 68 (1935). M.V.C.

Progress in the glass industry in 1933. II. OSCAR KNAPP. *Glashütte*, **64** [47] 775–77 (1934).—A brief discussion is given of researches dealing with (1) the system lime–iron oxide–silica, (2) gases dissolved in glass, (3) diffusion of monatomic gases by fused quartz, (4) theoretical and practical conclusions as to the strength of glass, (5) surface strength of glass, (6) viscosity measurements of variously composed glasses, (7) viscosity of some optical glasses, (8) effect of heat-treatment on viscosity, (9) relationship between properties and thermal strength of glasses, (10) critical temperature of glasses, (11) expansion measurements on glass, (12) effect of thermal treatment on the expansion of Pyrex-brand glass, (13) changes in thermal expansion with slow heating, (14) electrical behavior of glasses at room temperature, (15) electrolysis of glass at high temperature, and (16) changes in the coloring of glass on exposure. For Part I see *Ceram. Abs.*, **14** [1] 10 (1935). M.V.C.

Resistance to scaling and luminosity of glass paving blocks for translucent reinforced concrete. BERNARD LONG. *Verre & Silicates Ind.*, **6** [1] 2–4; [2] 17–21 (1935).—Determining the resistance to scaling and factors affecting the translucency of glass paving block imbedded in concrete are discussed. M.V.C.

Safety glass. C. A. REDFARN. *Brit. Plastics*, **5** [55] 298–99 (1933); abstracted in *Sprechsaal*, **67** [9] 124 (1934).—In safety-glass manufacture, the raw glass may be either drawn or rolled plate and the cellulose derivative, either ordinary nitrocelluloid or noninflammable acetate celluloid. Plate glass is employed when a safety glass with the minimum of distortion is required. The outlines of the Triplex process are described. Nitrocellulose is more flexible and easier to work with than acetate-celluloid and, when fresh, has a higher degree of clarity. Its disadvantage is that it begins to turn yellow with time because of its decomposition by sunlight with the liberation of colored oxides of nitrogen in the form of minute bubbles. Acetate celluloid, although not so transparent as the former, is not affected by light and remains colorless for a long time. M.V.C.

Sand in Fourcault sheet-glass factories. ANON. *Glashütte*, **63**, 726 (1933).—Several factories attempted to cheapen the batch by using poorer sands of larger grain size. The best size is claimed to be 0.4 to 0.5 mm., all above 0.6 or less than 0.2 mm. being rejected. Use of larger grain sizes means increase in melting time which can be met in tanks using floating bridges by altering their position to enlarge the melting end, but for tanks with fixed bridges such accommodation is impossible. Higher melting temperatures are then necessary. Drying of sand before batch mixing is recommended as a great accelerator of melting. It should not be used straight from the drier, but should be allowed to cool before mixing with the other batch ingredients; otherwise lumpiness results. (*J.S.G.T.*)

Significance of softness and the content in agents promoting softness in intermediate-layer foils for safety glass. FRITZ OHL. *Keram. Rund.*, **41**, 558–60 (1933); *Massen Wiss. Tech.*, **3**, 229–31 (1933); abstracted in *Chem. Zentr.*, **i**, 591 (1934).—Multi-layer safety glasses of a high

quality may be produced with pure nitrocellulose and acetylcellulose without additions of softening agents. M.V.C.

Sodium disulfate in the glass industry. I. I. KITAIGORODSKIĬ AND S. J. RAP. *Keram. i Steklo*, **8** [1] 36 (1932).—The Institute of Glass in Moscow verified on a factory scale the laboratory research work concerning the use of sodium disulfate in glassmelting. The disulfate, ground and passed through a sieve of 67-mesh/sq. cm., was thoroughly mixed with 5% charcoal, charged in a cold kiln in a layer not more than 150 to 200 mm. thick, and calcined. No deleterious action of the disulfate was observed on the fire brick of the kiln siege during the heating. After this procedure the disulfate was found to contain 0.11% free SO_3. A pot furnace at the experimental works of the Institute of Glass was used for melting the glass, SiO_2 74, CaO 12, and Na_2O 14%, employing the disulfate as the sole source of alkali. Cullet was not added. The resulting glass was semiwhite. No particular defects in the pots were observed after the melts with the disulfate. (*J.S.G.T.*)

Tank furnace heated with heavy oil. ALEXANDRE NADEL. *Chaleur & ind.*, **15** [169] 1173–74 (1934).—Details are given of special feeding installations insuring a stable temperature in a tank furnace for melting white glass for hollow glassware. The stable temperature is a function of the stability of (1) the quality (viscosity) of heavy oil, (2) its temperature, (3) pressure, (4) primary air, (5) secondary air, and (6) draft. M.V.C.

Theory and first experiment of the "thin-layer" method of glassmelting. I. I. KITAIGORODSKIĬ. *Keram. i Steklo*, **10** [12] 21–27 (1934).—The theory of the "thin-layer" method of glassmelting and the feeding of the tank with a continuous thin stream of batch are discussed in detail. Researches made at the Institute of Glass show the following results: (1) With increased fineness of grinding of raw materials, the reaction of the silicate formation proceeds more rapidly. (2) The time of formation of glass is greatly lowered with a decrease in the size of sand grains; the size of the sand grain has a greater effect on the melting time than marble grains, while the grain size of soda has no effect. (3) Increase of temperature from 1300 to 1400° considerably shortens the time of glass formation. When melting separate portions of the batch the process of glass formation occurs much sooner than when melting the batch in the usual way. (4) The reaction of the silicate formation in a layer of 1 cm. thickness proceeds more rapidly than when the batch has a thickness of 2 or 3 cm. (5) There is a rectilinear dependence between the time of the formation of glass and the size of the fritted particle melting. Experiments showed that (*a*) charging the batch in heaps slows down the formation of silicates and the process of refining; (*b*) the batch charged in heaps favors the formation of defects in the glass mass and lowers its quality; (*c*) the consumption of fuel is greatly lowered when the batch is fed continuously as a thin stream; this method decreases the magnitude of thermal shock and increases the life of refractories. M.V.C.

Variability of chemical resistance of glass. ANON. *Verre & Silicates Ind.*, **5** [23] 444–47 (1934).—Literature on the relation of the chemical resistance of glass to the composition is briefly reviewed. M.V.C.

Water jackets for glassmelting tanks. L. T. SHERWOOD. *Bull. Amer. Ceram. Soc.*, **14** [3] 119–20 (1935).

Weathering and corrosion of glass. W. E. S. TURNER AND VIOLET DIMBLEBY. Presented at meeting of Soc. Glass Tech., Sheffield, England, Oct., 1934. Abstracted in *Pottery Gaz.*, **59** [689] 1358–60 (1934). E.J.V.

BOOKS AND BULLETIN

Chemical research work of the State Optical Institute. ANON. Goschimtechisdat, Leningrad, 1932. 87 pp. This symposium describes research activities of the State Optical Institute at Leningrad in chemistry of glass, chemical physics, and photography during 1918–1932. P. BUDNIKOFF AND E. STEFANOWSKY

Collection of data for chemical analysis of raw materials, batch, and ordinary glass. N. I. SAMSONOV AND O. V. KRASNOVSKIĬ. All Union Sci. Eng. Tech. Soc. Glass and Porcelain Ind., Moscow, 1934. 40 pp. Price 95 kopecks. This booklet contains a brief discussion of methods of chemical analysis of kaolin, feldspar, lime, dolomite, magnesite, soda, sodium sulfate, batches of ordinary glass, and their composition. M. V. CONDOIDE

Colored glasses, their production and properties. V. V. VARGIN. Goskhimizdat., Leningrad, 1934. 106 pp. Reviewed in *Keram. i Steklo*, **10** [12] 40 (1934).—The principles of melting colored glass and properties of pigments used are described. A number of batches are analyzed, and data on flashed glasses are given. M.V.C.

Lessons on glass used by ceramists (Leçons sur le Verre á l'usage des Céramistes). BERNARD LONG. Dunod, Paris, 1935. 88 pp., 26 illustrations. Bound 15 F. 65 cts. This book contains the basic characteristics of glass and the control of ceramic materials because ceramic materials are constituted essentially by grains of crystalline materials soldered to each other by glass. The part dealing with viscosity is especially important because it discusses the effect of temperature on the viscosity of glass and the phenomena of deformation of ceramic materials at high temperature, either during their firing or when used in practice. A comparative study of the dilation of glasses and vitrified ceramic materials gives data on internal strains and intervals of annealing for stoneware, porcelain, and special refractories fired at high temperatures. Comparative results between calculations and direct measurements of thermal conductivity are dealt with in a special chapter. The last part deals with the temperature of devitrification and rate of crystallization of special stoneware. M. V. CONDOIDE

PATENTS

Adjustable mounting for shears of a glass feeder. E. H. CURTIS, JR. (Hartford-Empire Co.). U. S. 1,994,123, March 12, 1935.

Apparatus for handling glass batches. J. H. RITTER. U. S. 1,992,444, Feb. 26, 1935.

Apparatus for manufacturing laminated glass. B. C. CASE AND C. B. SCHAFER (Libbey-Owens-Ford Glass Co.). U. S. 1,989,268, Jan. 29, 1935.

Barrel-shaped glass tubes for labels. FIRMA C. ZEISS. Ger. 602,137, Aug. 16, 1934. The tube sections are mounted on mold cores and heated until they assume the correct shape, the cores being of such material that after cooling

the largest cross-section of the core was less than the smallest of the glass tube to permit withdrawal. (*J.S.G.T.*)

Building block. GAMES SLAYTER (Owens-Illinois Glass Co.). U. S. 1,991,469, Feb. 19, 1935.

Charge severing mechanism. C. W. SCHREIBER AND J. E. MCLAUGHLIN (Owens-Illinois Glass Co.). U. S. 1,991,705, Feb. 19, 1935.

Control of depth of immersion of suction molds to allow for change in glass level. E. FÉCHOZ. Ger. 598,832, May 31,1934. The mold-carrying arm in descending forces down a plunger in a cylinder filled with fluid which is driven through an aperture of adjustable size, control of this determining the depth of descent of the mold to suit the level of the glass surface from which it gathers. (*J.S.G.T.*)

Drawing glass rod or tube vertically upward. E. HANUS. Ger. 598,727, May 31, 1934. A container is fed with molten glass from a tank furnace, the flow being controlled by a valve. The pressure head of glass is balanced by one of heated gas or air applied through a pipe. The drawing nozzle is located sufficiently below the level of the glass in the tank so that the rod or tube is driven out therefrom notwithstanding the frictional losses in the tube. (*J.S.G.T.*)

Glass gathering and forming machine. FRANK O'NEILL (Owens-Illinois Glass Co.). U. S. 1,992,963, March 5, 1935.

Glassmelting tank. J. H. MCKELVEY AND J. W. ROGERS (Laclede Christy Clay Products Co.). U. S. 1,989,103, Jan. 29, 1935.

Glass tile and building block. H. W. COLLINS AND ELOY RUIZ (Owens-Illinois Glass Co.). U. S. 1,989,634, Jan. 29, 1935.

Glassware. T. W. MCCREARY. U. S. 1,993,412, March 5, 1935. The method comprises shaping a hollow glass shell, introducing a wire mesh into the shell and into intimate contact with the inner wall thereof, and expanding a charge of glass in the shell and against the exposed side of the mesh, the expansion being limited to such extent that the glass of the charge will not have contact with the shell at points between the strands of the mesh.

Glassware forming machine. L. D. SOUBIER (Owens-Illinois Glass Co.), U. S. 1,991,708, Feb. 19, 1935. FRANK O'NEILL (Owens-Illinois Glass Co.), U. S. 1,992,321, Feb. 26, 1935.

Hardening or toughening sheets of glass. F. ECKERT. Ger. 602,431, Aug. 23, 1934. The edges of window panes for vehicles are rounded either by grinding or melting until the radius of curvature of the edge is about equal to half the thickness of the sheet before being subjected to the hardening process in known manner. (*J.S.G.T.*)

Joining glass sheets. L. R. HODGE AND G. N. CRISFORD. Brit. 423,945, Feb. 27, 1935.

Kilns for manufacture of glassware. E. A. HAILWOOD. Brit. 423,589, Feb. 20, 1935.

Lens or cover glass for head lamps, etc. J. L. KOUBEK (General Motors Corp.). U. S. 1,992,668, Feb. 26, 1935.

Manufacture of plate or sheet glass by rolling. COMPAGNIES RÉUNIES DES GLACES ET VERRES SPÉCIAUX DU NORD DE LA FRANCE. Brit. 423,284, Feb. 13, 1935.

Method and apparatus for:

Conformation of glass sheets. SOC. ANON. DES MANUFACTURES DES GLACES ET PRODUITS CHIMIQUES DE ST.-GOBAIN, CHAUNY, ET CIREY. Brit. 423,566, Feb. 13, 1935.

Forming glassware. E. O. HILLER (Hartford-Empire Co.). U. S. 1,992,948, March 5, 1935.

Forming hollow glassware. G. E. HOWARD (Hartford-Empire Co.), U. S. 1,992,951, March 5, 1935. A. J. SMITH (Hartford-Empire Co.), U. S. 1,992,510, Feb. 26, 1935.

Manufacture of glass tubes, rods, etc. J. R. C. JORGENSEN. Brit. 422,947 and 423,148, Feb. 6, 1935.

Polishing sheet glass. D. H. GOODWILLIE (Libbey-Owens-Ford Glass Co.). U. S. 1,989,408, Jan. 29, 1935.

Method for manufacture of glass, etc., products. GASTON DELPECH (Soc. anon. des manufactures des glaces et produits chimiques de St.-Gobain, Chauny, et Cirey). U. S. 1,992,994, March 5, 1935.

Phosphate glasses. I. G. FARBENINDUSTRIE A.-G. Ger. 596,471, April 19, 1934. Addition to Ger. 580,295 (*Ceram. Abs.*, **13** [5] 118 (1934)). Phosphate glasses as described in the parent specification are modified in this one so that the ratio of P_2O_5 to Al_2O_3 is between 1 : 1 and 3 : 2. (*J.S.G.T.*)

Process and apparatus for producing laminated sheet glass. J. L. DRAKE (Libbey-Owens-Ford Glass Co.). U. S. 1,992,997, March 5, 1935.

Process and apparatus for producing safety glass. G. B. WATKINS (Libbey-Owens-Ford Glass Co.). U. S. 1,989,388, Jan. 29, 1935.

Process of producing curved composite glass. G. B. WATKINS (Libbey-Owens-Ford Glass Co.). U.S. 1,992,976, March 5, 1935.

Producing dichroic glasses. GLASHÜTTENWERKE VORM. J. SCHREIBER UND NEFFEN. Ger. 598,630, May 31, 1934. Glass of one color is cased with glass of another, the colors being so combined that the outer layer is wholly or partly transparent to the light transmitted by the inner one and the compound glass is optically inhomogeneous or is so when viewed in some particular direction. (*J.S.G.T.*)

Production of large-diameter rings of fused quartz. DEUTSCH-ENGLISCH QUARZSCHMELZE G.M.B.H. Ger. 594,706, March 8, 1934. A process for producing, out of fused quartz, rings or other bodies having a closed periphery of large diameter consists in embedding a previously bent-up ring of quartz in quartz sand at the seam and heating at this point to unite the ends. (*J.S.G.T.*)

Production of light-walled articles from tubing:forming bases. J. DICHTER. Ger. 603,095, Sept. 6, 1934. In a machine for making articles from tubing in which each tube section is taken past several heating stations and then drawn out, being next heated to form the bottom, a special heating burner is supplied for the latter purpose, together with a platform adjustable with respect to the bottom of the tube. (*J.S.G.T.*)

Production of tubular articles by machine. GERRESHEIMER GLASHÜTTENWERKE A.-G. VORM. FERD. HEYE. Ger. 596,276, April 12, 1934. Parisons formed on an automatic machine are blown out into tubular molds by air under pressure introduced through blowheads placed both above and below the mold. (*J.S.G.T.*)

Production of yellow, brown, and black glasses. F. H. ZSCHACKE. Ger. 599,563, June 14, 1934. In the produc-

tion of yellow, brown, or black glasses, the sulfur can be introduced by means of any sulfide, using arsenic trioxide as stabilizer. (*J.S.G.T.*)

Purification of silica sands, etc. Rockware Glass Syndicate, Ltd., and F. W. Adams. Brit. 423,053, Feb. 6, 1935.

Sheet-glass forming apparatus. J. L. Drake (Libbey-Owens-Ford Glass Co.). U. S. 1,992,998, March 5, 1935.

Sintering glass batch before melting. G. Keppeler. Ger. 597,081, April 26, 1934. Batch containing the sand in finely divided form is slowly heated so that the reactions are nearly completed at a temperature below that of glass formation. The resulting mass melts quickly when heated at a suitable temperature and in such a manner that the molten material can flow away from the unmolten, leaving the latter exposed to the full melting temperature. (*J.S.G.T.*)

Tilting pots in cast-plate process. Compagnie de Floreffe, Soc. Anon. Ger. 596,018, April 5, 1934. Means are provided for tilting the pot about a horizontal axis perpendicular to that of the rolls and at the same time displacing it in a direction parallel to the axes of the latter. (*J.S.G.T.*)

Transferring parisons from parison mold to blow mold. Soc. anon. d'études et de constructions d'appareils mécaniques pour la verrerie. Ger. 598,457, May 24, 1934. In a step-by-step rotating machine for making glass articles the transfer between the parison mold and the blow mold on their respective tables is made by lowering and raising the parison mold table at each step while the tables are stationary. (*J.S.G.T.*)

Structural Clay Products

Crushing strength, linear deformation, and the Jourdain value. Vladimír Škola. *Stavivo*, p. 382 (1933).—Jourdain's method can not replace the determination of crushing strength, but it yields values which might be used to classify and characterize ceramic and other structural material. Tables are given. Illustrated. See also "Resistance—" *Ceram. Abs.*, **13** [4] 96 (1934). R.B.

Effect of sugar solutions on the properties of lime mortars and sand-lime brick. Josef Matějka. *Stavivo*, p. 119 (1934).—A mortar made with a 1% sugar solution instead of water had double tensile, crushing, and transverse strengths (tensile strength even higher). The permeability to water was reduced to $^1/_6$ and the effect of weather by 30%. R.B.

Production of porous hollow brick. Anon. *Tonind.-Ztg.*, **58** [96] 1167–69; [97] 1185–87; [98] 1198–1200; [99] 1211–12 (1934).—The preparation of raw materials, machines used for preparing them, and the molding and firing of porous hollow brick are discussed in detail. M.V.C.

Relation of crushing strength of fired brick and their absorption. O. Kallauner. *Stavivo*, p. 332 (1933).—The crushing strength of brick may be affected by thermal expansion of quartz or mica; α-quartz changes into β-quartz at 573°C, into α-tridymite at 870°C in the presence of fluxes, and into β-cristobalite at temperatures higher than 1000°C. Mica particles suddenly grow between 500 and 750°C (according to their dispersity), divide into small leaflets, lose their translucency, and gain a metallic luster (reflection of light). Simultaneously most of the combined water is expelled (O. Kallauner and S. Seidl, 1925). The unfavorable effect of mica has also been pointed out by Matějka (1932). In some cases brick were completely disintegrated in the kiln by this effect of mica. Within the limits of 15 to 30% water absorption—and almost every brick falls within these limits—the empirical formula $p = 90 - 0.8\,(35 - n)^2$ may be used, where p = crushing strength and n = water absorption. R.B.

Separation cracking between various mortars and brick in existing brick structures. C. C. Connor. *Proc. A.S.T.M.*, **34** [Part II] 454–79 (1934).—This type of cracking was studied on 38 existing buildings to determine to what extent it appeared on the surface of brickwork where the workmanship was good, and whether there was any relation between the amount of separation cracking and the kinds of material used. The study included 7 mortars and 36 makes of brick. The amount of visible separation cracking in brick panels at each building was measured and was found to vary between 2.5 and 68.3%, with an average of 31.1%. The data obtained, when combined with facts developed by other investigators, appear to indicate that there are certain properties of brick and mortar which must occur in combination to produce a durable bond. The necessary types of brick and mortar are available to form combinations that fulfill the indicated requirements and give promise of producing brickwork with a low percentage of cracking, if the workmanship is of good quality. R.A.H.

Tentative standard specifications on delivery and test of sand-lime brick. O. Kallauner. *Stavivo*, p. 310 (1933).—The Czechoslovakian Ceramic Society submitted to the State Department of Public Work tentative specifications on sand-lime brick which have been proposed by the Union of Brick Industry. Two grades, high-duty and common-duty brick, are provided. The grain size of the sand shall not exceed 5 mm., the water absorption shall be at least 10%, and crushing strength (determined on cubes cut from the brick) at least 150 kg./cm.² for high-duty and at least 75 kg./cm.² for common-duty brick. R.B.

Tests on reinforced brick masonry columns. M. O. Withey. *Proc. A.S.T.M.*, **34** [Part II] 387–405 (1935).—Tests of thirty-two $12^1/_2$- x $12^1/_2$-in. brick columns 6 ft. high made with Chicago common brick and with Waupaca face brick are reported. The variables include three percentages of longitudinal and a like variation in lateral reinforcement together with two high-strength Portland cement lime mortars. The results indicate that the column strength varies directly with the strength of the masonry and the percentage of longitudinal steel and is increased by the use of lateral reinforcement. Strengths

of 5000 lb./sq. in. based on gross area and over 7000 lb./sq. in. on the cores after shell spalling were attained. For suitable reinforced brick masonry columns a factor of safety of 3.5 to 4.0 is suggested. See also *Ceram. Abs.*, **13** [4] 89 (1934). R.A.H.

PATENTS

Brick machine. H. E. Dunn and W. E. Dunn Mfg. Co. Brit. 423,473, Feb. 13, 1935.

Building element. Fritz Bauer. U. S. 1,991,837, Feb. 19, 1935.

Building structure and brick. O. A. Steuer. U. S. 1,992,785, Feb. 26, 1935.

Refractories

Application of refractories to the copper industry. A. G. Suydam. *Trans. Amer. Inst. Mining Met. Eng.*, **106**, 262–67 (1933).—Tests have indicated the greater suitability of suspended magnesite arches for copper reverberatory furnace roofs. Two comparatively new types of magnesite brick are the low-iron, hard-fired brick and the chemically bonded brick; the latter has the advantage of low first cost. The resistivity of acid-proof brick reduces current leaks in the refinery. Inherent weakness in bonding clays is overcome by the use of high-temperature cements. W.E.R.

Brick for Cowpers in the southeast of France. R. Leduc. *Chaleur & ind.*, **15** [169] 1118–19 (1934).—Data on the chemical composition and properties of refractory brick for Cowpers used in the southeast of France are given. A Cowper brick should have (1) an alumina content of about 20%, (2) a pyrometric resistance of 1650°, (3) a resistance to compression of 10 kg./sq. cm. at 1350°, (4) a homogeneous and dense texture, (5) a smooth surface. Tubular brick should be about 25 cm. thick. M.V.C.

Determination of specific heat of refractory materials at high temperatures. N. Losinsky and S. Herman. *Zavodskaya Lab.*, **3** [9] 831–38 (1934).—A method that can be used in plant laboratories has been worked out at the Ukrainian Institute of Refractory and Acid-proof Materials, based on the principle of the water-buffer calorimeter. The apparatus is of simple construction and is easy to work with. Data of great accuracy (errors not over 1%) are obtained with it. The calorimeter, with the exception of the receiver, is similar to calorimeters used for determining the caloric value of fuel. The average specific heat of several silica and grog brick at 20 to 750, 1000, and 1250° has been determined and the interval specific heat in the intervals of 750 to 1000° and 1000 to 1250° has been computed; formulas for computing real specific heat of each brick tested have been worked out. P.B. & E.S.

Dinas (silica)—law. D. Beliankin. *Centr. Mineral., Geol.*, **A**, 306–12 (1934); abstracted in *Chem. Zentr.*, **ii**, 3421 (1934).—Dinas brick show far-reaching physical and chemical changes in service in furnaces; thus, 4 distinct layers are formed in Dinas brick of Martin furnaces: (1) The first is an unchanged zone. (2) It is followed by a transfer zone of darker red-brown color, with a strong crystallization of tridymite and pseudowollastonite and red-brown glass. (3) This is followed by a black tridymite zone, in which the last remnants of quartz and pseudowollastonite disappear. The glass is darker. Orthosilicates and a large quantity of magnetite skeletons are formed in it. (4) The cristobalite zone is in the hottest place, in which tridymite changes into α-cristobalite with the usual "twin formation" which is characteristic for the additional change of $\alpha \longrightarrow \beta$-cristobalite. Here also glass orthosilicates and magnetite skeletons appear in the intermediate spaces. TiO_2, Al_2O_3, and CaO collect chiefly in the transfer zone (2), while Fe and Mn are concentrated in the tridymite zone (3). M.V.C.

Drying tank blocks. Anon. *Glashütte*, **64** [40] 659–60; [41] 674–75 (1934).—In drying by the moist air system, the drying chamber, or drying canal systems, is explained. The firing and requirements for tank blocks are discussed. M.V.C.

Effect of different technological treatments of sagger mixes on their physical properties. I. P. Romankevich and R. B. Angenitzkaya. *Keram. i Steklo*, **10** [12] 18 (1934).—This paper is a criticism of conclusions drawn by F. A. Zenkovich (*Ceram. Abs.*, **13** [10] 262 (1934)) on the effect of various technological treatments on the physical properties of sagger mixes. M.V.C.

Effect of fused alumina and boron oxide on plastic fire clays. D. G. Moore and R. K. Hursh. *Bull. Amer. Ceram. Soc.*, **14** [3] 106–12 (1935).

Effect of granulation of magnesite brick on their properties. Hermann Salmang and Paul Nemitz. *Sprechsaal*, **67** [47] 717–19; [48] 729–31; [49] 745–47; [50] 759–61; [51] 775–79 (1934).—From three kinds of sintered magnesite, designated as B, C, and D, 10 mixes of different granulation with a grain size of α = 5 to 2 mm., β = 2 to 0.25 mm., and γ = 0.25 to 0 mm. were produced. The mixes were aged, pressed under different pressures (hand pressing, 1000 kg./sq. cm., and 750 kg./sq. cm.) in steel matrixes, and fired for 12 hr. to 1500° and 8 hr. to 1480°C. Samples were also prepared from mix D; their granulation was x = 2 to 0.43 mm., y = 0.42 to 0.06 mm., and z = 0.06 to 0 mm.; the samples were pressed under 750 kg./sq. cm. and fired to 1480° for 8 hr. Such fineness produces a great change in the properties of the mixes. The series of cylinders produced were tested for their bending strength, resistance to pressure, softening under pressure, porosity, shrinkage, temperature stability, and thermal expansion in the temperature region from 20 to 1800°. The mechanical cold resistance to pressure and bending strength are raised when the shaping pressure and content in fine grains in the structure of the brick are increased. A high bending strength was found in bodies which showed high compression stresses in outer zones. The increase of the shaping pressure maintains or raises the temperature of compression. A certain content in coarse grains increases the temperature of the beginning of compression. The unstable softening under load is greatly raised when a higher shaping pressure and a suitable granulation are used. All brick of the series B_2 (1000 kg./sq. cm. pressure)

were not destroyed under a load of 2 kg./sq. cm. at 1700°. Apparent porosity was considerably decreased by a high shaping pressure and a suitable granulation. Bodies with the highest content in fine grains do not always show the lowest porosity. The linear shrinkage due to firing is lowered by 1/3 with a high shaping pressure and a suitable packing of grains. The resistance to sudden changes of temperature of magnesite brick depends on the high coefficients of expansion of periclase, especially on the size of grains used, and on the "glass" present between the separate grains; the latter lowers greatly the elasticity of the bond between the grains. The grains in these stable mixes do not split, which shows that this splitting of the grains is not necessary for the production of stable magnesite brick. The curves of thermal expansion of magnesite brick from 0 to 1800° showed an S-shaped course and from 1600 to 1700°, a steep rise. The thermal expansion up to 1000° can be lowered by 10% in B_2 mixes and 12% in C mixes through a change of granulation. It is due to a concentration of magnesia in the glass; MgO has a much lower expansion coefficient in silicates and glass than when present in the form of a free oxide. Microscopic tests of thin sections showed that because of an increased formation of flux, increased shaping pressure, or increase of the content in finest grains, the glass is distributed more finely, penetrates the periclase aggregates, and cements the grains better. The separate grains are attacked by the flux which is enriched by magnesia. The glass itself is not homogeneous. M.V.C.

Expansion of coke-oven silica brick. G. W. Kukolev and K. Shmukler. *Ogneuporui*, **2** [8] 9–13 (1934).—The dilatometric and cathetometric methods usually used do not give reliable data at temperatures of 1000 to 1300° because at these temperatures the transformations of quartz to modifications with a low specific weight (tridymite and cristobalite) are relatively slow as compared with the time of the tests. When investigating silica brick produced by several Ukrainian works, the following method was used by the Ukrainian Inst. Sci. Research on Refractories. Expansion curves up to 750° were obtained with a differential Chevenard dilatometer; for higher temperatures samples were cut out and fired at 1235, 1270, and 1350° for 20 to 22 hr. and then measured, thus giving data for higher temperatures. Specific weights were also measured and it has been demonstrated that such measurements may be used as a method for controlling expansion properties of silica brick used for coke ovens. P.B. & E.S.

Firing grog by the "black briquet" method. K. I. Popov. *Ogneuporui*, **2** [10] 27–31 (1934).—The experience of the cement industry on firing briquetted mixtures of clay with limestone and coal in automatic shaft kilns was taken as a starting point. The possibility of effective use of this method for firing clay to grog in the refractories industry was investigated. Kaolin and Piatikhatki clay were taken for the experiments, and anthracite, anthracite fines, and coke waste (fineness of grind, 18 to 20% residue on 4900-mesh/cm.^{2} screen) were taken as fuel. The mixture had a water content of 10% and was briquetted by the Kühl method at a pressure of 5 to 30 kg./cm.^{2} The briquets were fired at S.C.E. 14 in a reducing atmosphere. The coal burned out completely. The water absorption of briquets had a value of 10.2 to 14.4%. The refractoriness of briquets fell from 1/2 to 1 S.C.E. The investigation has a preliminary character and was carried out under laboratory conditions. P.B. & E.S.

Firing magnesite brick. II. J. H. Chesters and C. W. Parmeler. **III.** J. H. Chesters, G. L. Clark, and K. C. Lyon. Presented at meeting of Ceramic Society [England], Olympia, Sept., 1934. Abstracted in *Colliery Guard.*, **149** [3849] 653 (1934); for Part I see *Ceram. Abs.*, **13** [3] 62 (1934). E.J.V.

Gasworks practice, 1933. H. D. Greenwood. *Fuel Econ. Rev.*, **13**, 16–21 (1934).—The most important problem investigated by the Refractory Materials Committee of the Institution of Gas Engineers is the spalling of silica work in vertical retorts. The contributory factors are (1) penetration of scurf into the retort material and detachment of silica material during scurfing, (2) constitutional changes in the material when subjected to local high temperatures, (3) penetration of alkali from the ash of the coal, (4) variable temperatures in the zone where flaking is most pronounced and steep temperature gradients through the walls of the retort, and (5) mechanical wear due to rodding, scurfing, etc. Scurfing is probably the major factor in causing spalling. Refractory materials are attacked by alkali in either the liquid or gaseous condition. No satisfactory method has been developed for hot patching retorts. W.E.R.

Glass attack on refractory materials and their testing. Otto Bartsch. *Ber. deut. keram. Ges.*, **15** [6] 281–317 (1934); for abstract see *Ceram. Abs.*, **13** [2] 34 (1934). E.J.V.

Granulometric composition of silica masses. I. S. Smeljansky and L. V. Drazhnikova. *Ogneuporui*, **2** [10] 13–18 (1934).—Several authors demonstrated that the physical properties of silica brick depend largely on the granulometric composition of the mass, a higher density of the brick being obtained by an appropriate proportion between the different fractions. Experiments based on experimental selection of an optimal filling up of a given volume with grains of different dimensions were undertaken by the authors. Nine fractions from 0 to 6 mm. were prepared; material of different granulometric compositions was poured into a cylinder and shaken down to fill a volume of 250 cu. cm., and the volume weight was calculated, based on the initial and final volume of the material fed and on the volume porosity. The results obtained demonstrated that masses of highest density and volume weight may be obtained when all fractions are used in appropriate proportions. Removal of the coarser fractions resulted in changes for the worse. The form of grains does not influence the density of the mass, but the use of grains of an angular form, owing to their advantage in the physicochemical processes during the firing process, is recommended. The best results were obtained with compositions calculated on the basis of the Litzow curve for grog materials; the volume weight obtained was 1.96 to 1.99. P.B. & E.S.

Grog brick produced by the half-dry pressing method. N. I. Woronin. *Ogneuporui*, **2** [10] 4–12 (1934).—Results of plant laboratory investigations to improve the quality of brick produced by the plant are given. Clay of the following composition was taken (%): SiO_2 from 50.0 to 65, $Al_2O_3 + TiO_2$ 31.1 to 32.5, Fe_2O_3 1.3 to 1.6, ignition loss

10 to 12, water absorption of samples fired at 1350° 0.8%, firing temperature in a tunnel kiln 12 to 13 S.C.E. The following results were obtained: With the increase of time of mixing of the mass from 5 to 8 min., higher crushing test data were obtained; further increase led to their lowering. The use of grog of a lower porosity led to an improvement of the strength of brick and to a lowering of its porosity. The use of grog of the following granulometric composition led to the best results: 2 mm. 25%, 0.5 to 2 mm. 25%, 0.5 mm. 50%. An addition of molasses to the mass led to negative results because it burned out at the firing temperature. Best results were obtained with the slip method of production (nearly all output being of first-grade brick) which is described extensively.

P.B. & E.S.

Guarded radiation plate method for the determination of thermal conductivity of refractories at elevated temperatures. C. A. PETERSON. *Jour. Amer. Ceram. Soc.*, **18** [4] 128–34 (1935).

High-grade semiacid ladle linings. S. A. GICHAREVITSCH AND G. L. KOGAN. *Ogneuporui*, **2** [11] 12–22 (1934).—Brick for ladle linings should possess the following properties: (1) refractoriness not under P.C.E. 32 to 33, (2) resistance to the chemical influence of liquid slag at temperatures over 1640°, (3) dense and identical structure for the whole lining, (4) high resistance to spalling, (5) high constancy of volume, (6) regular geometric shape. For the load test, deformation should not begin under 1320° with an interval of 250° to the point of 40% deformation. Mechanical strength should be 120 kg./cm.^{2} P.B. & E.S.

Highly aluminous materials in the manufacture of pots for melting optical glass. G. L. EFREMOV AND K. G. KUMANIN. *Keram. i Steklo*, **10** [12] 13–18 (1934).—The conclusions of studies are as follows: (1) The introduction of finely ground kyanite into the mix for glassmelting pots considerably increases the resistance of the pots to the attack of the glass melt. (2) The most effective method was that of using protective kyanite coats on the inside of the pot. (3) The thermal stability of the pots is greatly increased when using a dense lining on a porous body. (4) Refractory clay with a high iron content may be used for the production of the pot body without affecting the quality of the glass, provided that it is coated with a protective layer. M.V.C.

High temperature insulation for industrial furnaces. III. N. ALLEN HUMPHREY. *Blast Fur. Steel Plant*, **23** [2] 134–35 (1935).—Graphs showing thermal resistance of refractory materials, high-temperature insulating materials, and outside surface temperatures and heat losses based on total thermal resistance, to be used in calculating heat losses and temperature gradients for furnace walls comprised of two or more component parts, are explained, and an example of the calculations involved is given. For Part II see *Ceram. Abs.*, **14** [4] 95 (1935). E.J.V.

Influence of conditions of production of magnesia brick on its durability. S. N. MYSHKIN. *Ogneuporui*, **2** [8] 41–48 (1934).—The article contains the results of an investigation carried out by the laboratory of the "Magnesite" works at Satka (Ural) and contains data on the properties of magnesite produced under varying conditions: different granulation, water content, storage time of the mass, additions of red clay and ground construction brick, additions of molasses and of magnesium chloride, masses of different magnesite rock, "hot" masses, temperature of storage, stress of press, speed of raising the stress of the press, length of highest stress, length of drying of pressed brick, temperature of drying, and firing temperature.

P.B. & E.S.

Influence of granulometric composition of quartzites on properties of silica brick. I. S. SMELJANSKY AND L. V. DRAZHNIKOVA. *Ogneuporui*, **2** [11] 4–12 (1934).

P.B. & E.S.

Industrial furnace-construction improvements. H. M. CHRISTMAN. *Ind. Heating*, **2** [1] 23–24 (1935); see also "Greater efficiency—" *Ceram. Abs.*, **13** [10] 262 (1934).

M.H.

Mattagami River refractory clays. A. E. HILDER. *Can. Mining Met. Bull.*, No. 275, pp. 110–22 (1935).—Refractory clays occur on Mattagami River seven miles north of Smoky Falls, Ont., terminus of a private railway. The deposits consist of transported decomposition products of igneous rocks. Tests on the clays are given. G.M.H.

Monolithic tamped periclase converter linings at United Verde Copper Company smelter. F. H. PARSONS. *Trans. Amer. Inst. Mining Met. Eng.*, **106**, 153–64 (1933).—In a tamped lining of grain magnesite to replace magnesite brick, the following binders were tried alone and in combination: fire clay, crude bauxite, calcined bauxite, sulfuric acid, boric acid, blackstrap molasses, and crude-oil sludge. The best results were obtained with mixtures of periclase, fire clay, and sulfuric acid, or periclase, molasses, and sulfuric acid. Since 1930 all converting at United Verde has been done in shells with tamped periclase linings, except that one shell lined with magnesite brick has been regularly operated for comparison. W.E.R.

Optical investigation of emeralds and other minerals colored by chrome. PHILLIP VOGEL. *Neues Jahrb. Mineral., Geol.*, **A68**, 401–38 (1934); abstracted in *Chem. Zentr.*, **ii**, 3369 (1934).—Data on the optical properties of various emeralds, rubies, spinel, and corundum are given.

M.V.C.

Properties of refractory special mixes. MARCEL LÉPINGLE. *Ind. chim. belge*, **5**, 393–403 (1934); abstracted in *Chem. Zentr.*, **i**, 132 (1935).—The composition and physical properties of a great number of refractory materials having an acid and basic character and manufactured in various European countries are given in tables. M.V.C.

"Radex" magnesite brick, constituents and properties. P. P. BUDNIKOFF AND B. J. PINES. *Jour. Amer. Ceram. Soc.*, **18** [4] 125–27 (1935).

Rammed refractory linings. B. GALE. *Foundry Trade Jour.*, **48** [871] 300 (1933); from *Referatkartei der Silikatliteratur*, No. 5 (1934). M.C.S.

Reactions in cupola refractories. R. E. APTEKAR. *Refrac. Jour.*, **11** [1] 20 (1935).—The four major zones of the cupola, (1) crucible, (2) melting zone, (3) zone at and below the charging door, and (4) zone above the charging door, require carefully selected refractories if successful operation is to be expected. Basic refractories find little use due to their poor mechanical resistance to shock and abrasion. Siliceous materials are used only in the melting zone. Clay refractories, both in the raw state as a ramming material and also as fired block and shapes, are widely used throughout the cupola construction. M.C.S.

Refractories. R. P. HEUER. *Trans. Amer. Inst. Mining Met. Eng.*, **106**, 278–81 (1933).—A new type of suspended roof of magnesite for copper-smelting reverberatory furnaces lasted seven times as long as the former roof of silica. W.E.R.

Refractories based on diatomites. A. S. BASILEVITSH. *Ogneuporui*, **2** [10] 32–38 (1934).—Diatomites are being used to produce thermo-insulating building materials; the possibility of using them as a raw material to obtain refractories with thermo-insulating properties was investigated. Two kinds of diatomites were taken; the chemical compositions of that from Inza and that from Dobusha were, respectively, SiO_2 80.99 and 78.79, Fe_2O_3 2.83 and 4.03, Al_2O_3 7.57 and 10.48, CaO 0.68 and 0.92, MgO 0.71 and 0.80, ignition loss 5.59 and 3.92; refractoriness 1540 and 1450°C. The process used was similar to that of producing grog refractories. The refractoriness of the diatomites corresponded to that of refractory clays. Better load test data were obtained. Fifty per cent and 40% of moisture were needed for molding. The linear setting was a trifle higher than for clay. Best results were obtained with a firing temperature of 1200°, resulting in a thermal conductivity of the fired material of 0.47 (0.65 of the thermal conductivity of usual grog refractories); this means a possible economy of warmth of 35 to 50%. The material can be used at 1240 to 1300°. Quartzite and sawdust were used as additions. P.B. & E.S.

Refractories for the glass plant. R. BARTA. *Sklarske Rozhledy*, p. 133 (1933).—Requirements for glasspots, their classes, raw materials, preparation, molding, drying, and firing, are given. Tank blocks are discussed. R.B.

Refractory materials behavior under torsion at different temperatures. II. Kaolin-quartz and kaolin-vitreosil mixtures. A. L. ROBERTS AND J. W. COBB. Presented at meeting of Ceramic Society (England), Olympia, Sept., 1934; abstracted in *Colliery Guard.*, **149** [3849] 653 (1934); for Part I see *Ceram. Abs.*, **12** [10–11], 375 (1933). E.J.V.

Refractory materials for steam-boiler furnaces in practice. W. MIEHR. *Wärme*, **57**, 579–83, 599–602 (1934); abstracted in *Chem. Zentr.*, **i**, 132 (1935).—The properties and composition of various refractory materials used in steam-boiler furnaces are discussed in detail on the basis of practical experience. M.V.C.

Refractory materials, their use and production. ALFRED H. LAWLESS. *Heat Treating & Forging*, **20**, 252–53 (1934); abstracted in *Chem. Zentr.*, **i**, 132 (1935).—A brief review is given. M.V.C.

Refractory products for thermal exchangers. V. BODIN. *Chaleur & ind.*, **15** [169] 1143–46 (1934).—The characteristics of refractories used in thermal exchangers and accumulators and conditions to which they are subjected during working are discussed. Data on the composition and properties of English, French, and German refractory brick for blast-furnace recuperators (mostly of the Cowpers system) are given in a table. M.V.C.

Relation of refractory grog materials to influence of carbon monoxide. P. P. BUDNIKOFF AND D. NIERENSTEIN. *Stal*, **7**, 48–52 (1934).—The question of the influence of carbon monoxide on refractory linings of furnaces is of real practical importance. Its destructive influence is caused by the reaction, $2CO \rightleftarrows CO_2 + C$, which takes place under the catalytic influence of iron oxides contained in the refractory brick and leads to deposition of carbon which leads to destruction of the lining. Investigations by different authors are described. Investigations by the authors to find the conditions under which grog brick would be the most resistant to the influence of CO are described. The following conclusions were made: iron oxides and sulfides contained in the clay or taken into the mass during its working up in machines for the most part change to iron oxide. This acts as a catalyzer to the above-mentioned reaction. The optimum temperature for the reaction is 450 to 500°; at higher temperatures it goes in the inverse direction and no depositions of carbon are observed. The destruction of grog refractories is higher around iron spots. An important factor for the resistivity is the volume porosity of brick on which their permeability to gases depend. A very small addition of copper sulfate to the charge improves the resistivity of grog materials to CO, and this circumstance should be investigated more extensively. The following practical suggestions are made: the iron content (computed as Fe_2O_3) must not surpass 1 to 1.3% which can be attained by careful mechanical cleaning of clay and electromagnetic separation of the charge; this quantity of iron must be regularly distributed in the mass; an elevated density of the brick is required, the volume porosity not surpassing 18%; the firing of grog refractories in the temperature interval of 1300 to 1500° is desirable in a reducing atmosphere, as the ferric compounds formed at this temperature make the brick dense and catalyze the formation of mullite. Under the above conditions a protective "crust" forms on the surface which improves the chemical resistivity of the brick. P.B. & E.S.

Researches on the self-regulating resistivities of silicon carbide. I. V. KURCHATOV, N. A. KOVALEVA, T. S. KOSTINA, AND L. I. RUSINOV. *Zhur. tekh. Fisiki* [Series B], **3**, 1163–84 (1933); abstracted in *Chem. Zentr.*, **i**, 3245 (1934).—The curve of current potential of SiC resistances corresponds to the equation $I^{\alpha} R = C$ (constant), where α fluctuates between 0.6 and 0.8 and C lies between 1500 and 10,000. The effects of the temperature of treatment, shaping pressure, content in binders (quartz, alumina, feldspar), and grain size on α and C were studied. M.V.C.

Selection of refractories for use in the engineering industries. W. J. REES. *Fuel Econ. Rev.*, **13**, 50–53 (1934). —R. describes briefly the properties that affect the durability of refractories in service, principally in boiler furnaces. W.E.R.

Siliceous refractory products. MARCEL LÉPINGLE. *Verre & Silicates Ind.*, **5** [22] 417–22; [23] 440–43; [24] 457–63 (1934).—Physicochemical properties, the raw materials and manufacture, the composition and structure, and characteristics of extra-siliceous (Dinas) brick are studied. M.V.C.

Silicon carbide muffles. V. I. SAVCHENKO. *Ogneuporui*, **2** [10] 38–40 (1934).—S. attempted to find the best composition of a mass for making high-refractory silicon carbide muffles and muffle tile from Latninsky clay (refractoriness 1730°, SiO_2 54.74, TiO_2 1.41, Al_2O_3 31.16, Fe_2O_3 0.69, CaO 0.41, MgO 0.36, SO_3 0.20, ignition loss 11.03%). Best results were obtained with 80% silicon carbide and 20% clay. The hand-ramming method was used for

molding and the firing took place at 1300, 1380, and 1450° (held 3 hr. at the highest temperature). A muffle kiln showed a 10 to 12% increase in output and a 20% saving in fuel and worked uninterruptedly for 5 months with the use of these tile. P.B. & E.S.

Silicon carbide refractory saggers. E. ALESSANDRI. *Ind. Vetro & Ceram.*, pp. 408–48 (Oct., Nov., 1934); abstracted in *Verre & Silicates Ind.*, **6** [1] 10 (1935).—The following conclusions are given: (1) A mixture of crystallized silicon carbide of best quality and a very plastic clay gives durable refractory saggers for firing porcelain, especially flat pieces. (2) The quality of the silicon carbide is an important factor. (3) The mixing proportion and the furnace must be carefully considered. (4) Cost is important. M.V.C.

Standardization of refractory products. VLADIMÍR ŠKOLA. *Stavivo*, p. 89 (1934).—A survey of foreign and Czechoslovakian literature is given. In Czechoslovakia the following items are discussed: (1) nomenclature, (2) ultimate analysis and softening point, and (3) classification of products. It is recommended that standardization of shapes and dimensions be confined to standard brick and wedge-shaped brick. The Czechoslovakian refractory industry is for the main part an export industry and therefore foreign standards are of more importance than domestic standardization. Of Czechoslovakian workers Kallauner, Brabec, Spazier, and Barta are mentioned. R.B.

"Steel mixture" refractories for boiler furnaces explained. MCLEOD & HENRY CO. *Gas Age-Rec.*, **75** [6] 130 (1935).—"Steel mixture" refractory blocks made of specially selected flint clays ground and fired do not become plastic or fuse at temperatures below 3180°F. They possess high mechanical strength. E.J.V.

Testing the attack of slag. S. SACHS. *Tonind.-Ztg.*, **58** [98] 1195–97 (1934).—Experiments to determine the attack of cupola-furnace slag and Martin-furnace slag on various kinds of grog and silica brick are discussed. Details as to the method of procedure are given. Illustrated. M.V.C.

Thermal diffusivity of poor conductors. E. D. VAN REET. *Proc. Phys. Soc.*, **46**, 537 (1934).—A new method of determining the thermal diffusivity of poor conductors is described. An irregularly shaped block may be used provided that it has a fairly large plane surface. Temperature observations are made at two points within the block either by imbedding thermocouples or by inserting them between cut surfaces. Temperature intervals of less than 10° are used, and only a distance and quantities proportional to the temperature changes at the two points need be measured. (*T.C.S.E.*)

Viscosity of slags and its application to slagging of refractory brick. F. HARTMANN. *Ber. deut. keram. Ges.*, **15** [7] 375–90 (1934).—The work already done on slags, their melting points, and viscosities is reviewed. How this knowledge can be used to solve the problem of the slag erosion of refractory brick is explained. See also *Ceram. Abs.*, **13** [9] 244 (1934). E.J.V.

BOOKS AND BULLETINS

Applications of insulating refractories to industrial refractories. J. D. KELLER. *Amer. Refrac. Inst. Tech. Bull.*, No. 53, 8 pp. (1934).—These new refractories find their chief application in intermittently operated furnaces. The furnaces heat quicker. Savings of several hundred per cent of the cost of the brick are shown. Troublesome drawbacks are spalling and increased permeability to gases. The latter is overcome by a thin coating of plastic refractory placed on the inner surfaces. In most cases these brick should be laid with mortar. Because the brick are light and easily cut to shape they are adapted to the construction of various forms of suspended arches. See also *Ceram. Abs.*, **13** [5] 121 (1934). W.E.R.

Chromite. ROBERT H. RIDGWAY. Reprint from U. S. Bur. Mines Minerals Yearbook, 1934 (*Ceram. Abs.*, **14** [2] 51 (1935)). 10 pp. Price 5¢. R.A.H.

High-alumina refractory materials. P. P. BUDNIKOFF. *Reference Leaflets of Central Council of All-Union Inventors' Soc.*, Vol. 12, No. 221 (1933—issued 1934).—A classification of refractory materials shows the place of high-alumina refractories among these materials. A description of uses, raw materials used and their characteristics, preparation of the mass, molding, drying, and firing of brick is given. A scheme of production is shown. The characteristic quality of different kinds of high-alumina refractories, with special reference to those produced in the U. S. A., is shown. A method of producing ladle plugs and nozzles is given. Bibliography. P.B. & E.S.

Observations on glasshouse refractories. W. L. FABIANIC. *Amer. Refrac. Inst. Tech. Bull.*, No. 54, 12 pp. (1934).—Present specifications are not a satisfactory guide to the selection of glasshouse refractories. Glasshouse refractories should be well fired, uniform as to size, weight, and composition, and have uniform and controlled thermal expansion. Several examples of failure in service are discussed. Illustrated. W.E.R.

Symposium on problems of rationalization and plant construction in the refractories industry. Edited by M. P. KLEINSTEIN AND A. K. FREBERG. State Inst. for Designing Plants of the Refractories Ind. "Giproogneupor," Leningrad, 1934. 238 pp. The symposium contains four articles on actual problems of the refractories industry of the U.S.S.R. An article by V. G. Viakhirev and S. W. Babus treats the fundamental technical and economic problems of the development of the refractory industry in the Ural; an article by M. M. Shirikov deals with the problems of new mining methods; A. D. Zepin discusses the rationalization of driers and kilns; A. K. Freberg describes the development of the dry-pressure method of production of grog brick. P.B. & E.S.

PATENTS

Centrifugal casting of carbide, etc., materials. J. H. L. DE BATS. U. S. 1,993,774, March 12, 1935.

Diatomaceous product and method of making. C. C. SCHUETZ (Johns-Manville Corp.). U. S. 1,992,547, Feb. 26, 1935.

Furnace wall. B. M. JOHNSON (Carborundum Co.). U. S. 1,992,620, Feb. 26, 1935.

Furnace wall structure. F. J. TONE (Carborundum Co.). U. S. 1,992,587, Feb. 26, 1935.

High-pressure brick containing magnesia and process of making. R. P. HEUER (General Refractories Co.). U. S. 1,992,482, Feb. 26, 1935.

High-pressure chrome refractory. R. P. HEUER (General Refractories Co.). U. S. 1,992,483, Feb. 26, 1935.

Permeable ceramic diaphragm. R. C. BENNER AND H. N. BAUMANN, JR. (Carborundum Co.). U. S. 1,993,955, March 12, 1935. A process for producing a permeable ceramic article comprises providing a slip whose permanent ingredients consist principally of magnesia, alumina, and silica in approximately the proportions by weight of 13, 35, and, 52, respectively, casting the slip in the desired shape, drying the casting, and firing at a temperature between 1300 and 1400°C to convert the casting into a body which is crystalline.

Permeable ceramic material and process for making. H. E. JOHNSON (Johns-Manville Corp.). U. S. 1,992,916, Feb. 26, 1935. A method of manufacturing porous ceramic products comprises mixing argillaceous material, a gas-evolving agent, a comminuted combustible substance, and water to form a plastic slip, permitting the evolution of bubbles of gas throughout the mixture while in a fluid state, drying the resulting mass, and subjecting the dried mass to a high temperature adapted to burn out the admixed combustible matter and develop a ceramic bond in the mass.

Process for making diatomaceous earth products. A. F. ECHBERG. Brit. 424,110, Feb. 27, 1935.

Process of sintering and fusing quartz. FRITZ WINKLER (I. G. Farbenindustrie, A.-G.). U. S. 1,992,594, Feb. 26, 1935.

Refractory material and method of making. C. E. WILLIAMS AND J. D. SULLIVAN (Battelle Memorial Institute). U. S. 1,994,377, March 12, 1935. The method of producing a hydraulic cement comprises selecting a clinker formed by firing a mixture of a calcareous magnesium carbonate material, silica, and a metal oxide fluxing agent, the silica in the mixture being present in an amount of from 5 to 11% and the metal oxide fluxing agent being present in an amount of from 0.5 to 15%, at such a temperature and for such a period of time as to produce a clinker consisting primarily of periclase, tricalcium silicate, and a calcium salt in which the oxide of the fluxing agent is the acid radical thereof which is stable against slaking and dusting, and reducing the clinker to powdered form to produce a hydraulic cement.

Terra Cotta

Floor rating after continued service. C. H. GEISTER. *Keram. Tile Jour.*, **7** [1] 8 (1935).—In determining the adaptability of ceramic tile for use in hospitals, a study was made of all types of flooring materials. The investigation showed that ceramic tile floors are highly desirable due to their resistance to wear, stains, chemicals, and deterioration due to moisture and temperature changes. Tables show the results of the tests. M.C.S.

Insulators pass rigid tests. ANON. *Ceram. Ind.*, **24** [3] 155 (1935).—Porcelain insulators for Pennsylvania Railroad electrification are given a routine mechanical test involving a tensile load on a string of six insulators equal to 40% of their rated strength, and then on a continuous moving electrical test conveyer they are given a 5-sec. high frequency flashover test and a 5-min. 60-cycle flashover test. A final inspection for improper alignment of hardware or any other defect follows these tests. E.J.V.

Manufacture of general and domestic stoneware. N. D. WOOD. Presented at meeting of Ceramic Society [England], Stoke-on-Trent, Jan., 1935. *Pottery Gaz.*, **60** [693] 389–90 (1935).—An instructive lecture regarding the field covered by the stoneware industry and production methods adopted in the particular branch of pottery manufacture is presented. E.I.V.

Raschig rings in filter for sewage treatment. H. R. LUEBBERS. Presented at Iowa Clay Workers Short Course, Iowa State College, Ames, Iowa, Jan., 1935. *Brick Clay Rec.*, **86** [2] 63–64 (1935).—After describing the various types of filter bed materials used, L. points out that comparative tests now in progress tend to indicate that Raschig rings, a new clay product, may prove the best for sewage treatment. Data for the amount of filter media required for a small town's sewage treating plant are given. E.J.V.

Reddish colorations in unsintered high-quartz bodies. E. BERDEL. *Ber. deut. keram. Ges.*, **15** [4] 179–82 (1934).—Having encountered reddish colorations in stonweare and sanitary porcelain bodies high in quartz content, B. conducted an investigation to determine the cause. It was found to occur during reducing firing and disappeared in oxidizing fires. Study and tests showed that an excess of sulfide gas in the kiln atmosphere could cause this coloration. It was also found that the reduction product of silica, silicon monoxide, SiO, was red in color, and on using a reducing fire it was possible to produce the red color by reduction of silica. To prevent occurrence of the red coloration the reducing fire must be held below red heat and the finishing off must be strongly oxidizing. E.J.V.

Salt glaze. II. Reaction of mixed water vapor and sodium chloride on alumina, feldspar, kaolin, and synthetic bodies. Treatment of waste gases. S. KONDO AND S. SUZUKI. *Jour. Soc. Chem. Ind.* [Japan], **37** [11] 702–703*B* (1934).—The method of procedure and results are given. **III. Manufacture of sodium silicate.** *Ibid.*, **37** [11] 703*B* (1934).— Fairly good results were obtained with a mixture of crude table salt and powdered quartz in the proportion 2.5 : 1 when heated at higher temperatures with small after-additions of salt. **IV. Microscopic observations of commercial salt-glazed ware.** *Ibid.*, **37** [12] 737–38*B* (1934).—The characteristics of Japanese salt glaze are given. **V. Slip glaze.** *Ibid.*, **37** [12] 738*B* (1934).—The effects obtained by varying the composition of slip glazes are given. For Part I see *Ceram. Abs.*, **13** [11] 295–96 (1934). M.V.C.

Stoneware tile of large size as a novelty in ceramic production. V. PILAŘ. *Stavivo*, p. 34 (1934).—The dimensions of the tile are 10 x 10 cm., 15 x 15 cm., 20 x 20 cm., 25 x 25 cm., 30 x 33 cm. (Rakoflor), and 40 x 40 cm. (Rakogrand). R.B.

Variation of structure of terra cotta products as a function of the quantity of water for shaping. V. BODIN. *Centro Studi Ceramici*, **1** [4–5] 40–42 (1934).—An examina-

tion with a polarizing microscope will show whether a terra cotta product has been shaped from a wet, thick, or hard paste or pressed powder. M.V.C.

PATENTS

Process for covering walls. HEINRICH BORSARI-FISCHER. U. S. 1,993,472, March 5, 1935. The process uses facing plates of resistant hard material such as glass, earthenware, etc.

Tile, brick, etc. MARBELLO & DURUS, LTD., AND F. M. S. KENT. Brit. 423,901, Feb. 20, 1935.

Whiteware

Fireclay ware or sanitary porcelain? GEORG HEINSTEIN. *Ber. deut. keram. Ges.*, **15** [4] 183–98 (1934).—Fireclay ware is superior due to its higher resistance to damage by blows. Only a few models can be produced in one firing of sanitary porcelain, while in fire clay the largest can also be made, such as bathtubs. In other properties fire clay and sanitary porcelain are the same with regard to their serviceability. Sanitary porcelain has the advantage of lower freight cost due to lower weight and shows greater profits on exporting. E.J.V.

Influence of the composition of high-voltage porcelain on its properties. A. N. EGOROV. *Trans. VI Mendeleiev Congress Theoretic and Appl. Chem.*, **2**, 504–13 (1934). P.B. & E.S.

Kaolins of Torniella. P. FERRAZZI. *Centro Studi Ceramici*, **1** [4–5] 43 (1934).—These kaolins are shown to be excellent for fine and hard porcelain. M.V.C.

Relation of the technical properties to the degree of grinding of porcelain. E. KEMPCKE. *Ber. deut. keram. Ges.*, **15** [5] 249–54 (1934).—With increasing fineness of grind the castability of the body, specific gravity, and drying speed decrease, and the water requirement is greater. The dry transverse strength, the fired tensile strength of cast test pieces, and their resistance to puncture is increased with increasing fineness of grind, while the mechanical strength of turned bodies is lower. With increasing degree of fineness the white color and transparency increase. The loss in weight of fired porcelain after exposure to hydrofluoric acid is almost the same in all cases, the solubility being only slightly less with greater fineness of grind. E.J.V.

Russian chinaware: a microscopic study. GEORGE JAMES MIDDLETON. *Bull. Amer. Ceram. Soc.*, **14** [3] 101–104 (1935).

Sanitary ware made of semiporcelain. V. P. ZUBCHANINOV AND A. G. SHTEINBERG. *Keram. i Steklo*, **10** [12] 27–29 (1934).—Experiments with mixes made of various kinds of clays are described. Glazes developed for them are discussed. The results are shown in tables. M.V.C.

PATENTS

Bushing insulator. A. O. AUSTIN (Ohio Brass Co.). U. S. 1,994,267, March 12, 1935.

Fog-type insulator. J. T. LUSIGNAN, JR. (Ohio Brass Co.). U. S. 1,994,282, March 12, 1935.

Insulator. A. O. AUSTIN (Ohio Brass Co.), U. S. 1,994,265 and 1,994,266, March 12, 1935. J. T. LUSIGNAN, JR. (Ohio Brass Co.), U. S. 1,994,281, March 12, 1935. W. A. SMITH (Ohio Brass Co.), U. S. 1,994,291, March 12, 1935. J. J. TAYLOR (Ohio Brass Co.), U. S. 1,994,292 and 1,994,293, March 12, 1935.

Method and apparatus for protecting electrical insulators. C. B. THORNE. U. S. 1,994,250, March 12, 1935.

Water closet. SVEN DUNER (Duner Co.). U. S. 1,992,653, Feb. 26, 1935.

Equipment and Apparatus

Applied engineering in pugging. H. R. STRAIGHT. Presented at Iowa Clay Workers Short Course at Iowa State College, Ames, Iowa, Jan., 1935. *Brick Clay Rec.*, **86** [2] 56–60 (1935).—Streamlining the pugging knives benefits all clays. Proper design of knives to apply pressure as in kneading bread, curving the blade to produce draw cuts to make the front edge of the knife self-sharpening as it wears away, and using a ductile shank to prevent breakage of the knives are means of improving both the efficiency and quality in pugging clay. E.J.V.

Automatic humidity controller. NEGRETTI AND ZAMBRA. *Jour. Sci. Instruments*, **11** [10] 329 (1934).—A hygroscopic element in a tubular air channel operates an air-leak valve in controlling the humidifying or dehumidifying to maintain a constant relative humidity. Illustrated. J.L.G.

Characterization of color by determining the white content with a photoelectric reflection measurer. H. HARCORT. *Sprechsaal*, **68** [2] 17–19 (1935).—The photoelectric reflection measurer of B. Lange (*Ceram. Abs.*, **13** [10] 269 (1934)) can be used successfully for determining the white content of ceramic raw materials and finished products. The white content is determined from the precipitated barium sulfate. Therefore it is possible to characterize the firing color of clays and kaolins. Fine ceramic ware can be compared, and the effect of the firing temperature upon the color of the finished products, *e.g.*, porcelain, whiteware, and tile, can be determined. The covering power and resistance of glazes can be determined numerically. M.V.C.

"Comfo" respirator. MINE SAFETY APPLIANCES CO. *Ind. Finishing*, **11** [2] 34–35 (1934).—A new low-priced dust respirator is characterized by two dust filters, one lying over each cheek. This allows the filters to be removed from the path of the moisture-laden exhaled air and the filter area to be greatly increased. Low breathing resistance and long filter life are obtained as a result. Illustrated. J.L.G.

Continuous filtration effected on an endless belt.

CANADIAN LOCOMOTIVE CO., LTD. *Eng. Mining Jour.*, **135** [12] 580 (1934). J.L.G.

De-airing problems solved. ERNEST W. KNAPP. *Brick Clay Rec.*, **86** [2] 61 (1935).—Defects evident after drying were traced to clay preparation and it was shown that less pugging is required when de-airing the clay. Power consumption is reduced by properly adjusting auger knives and shafts to meet new conditions. E.J.V.

De-airing dry-press and stiff-mud bodies for clay products manufacture. W. C. RUECKEL AND R. B. KEPLINGER. *Proc. A.S.T.M.*, **34** [Part II] 480–89 (1934); see also *Ceram. Abs.*, **14** [4] 93 (1935). R.A.H.

Design of modern industrial piping systems: Flow of fluids. F. L. SNYDER. *Heating, Piping, & Air Conditioning*, **7** [1] 5–11 (1935).—A series of charts on pressure drop and viscosity conversion is given and their use is explained in designing piping systems to carry fluids. J.L.G.

Drying chamber heated with flue gases. KÖCHLING. *Tonind.-Ztg.*, **58** [85] 1031–35 (1934).—Details of experiments in using flue gases for drying chambers are given. Illustrated. M.V.C.

Drying solid materials. VI. Relationship between rate of drying and direction of air. S. KAMEI, S. MIZUNO, AND S. SHIOMI. *Jour. Soc. Chem. Ind.* [Japan], **37** [10] 626–30*B* (1934).—It was found that a current of air blowing parallel to the surface of the body exerts the greatest effect on drying. Tables and diagrams illustrate the discussion. **VII. Drying of cellulose or pulp.** *Ibid.*, **37** [11] 657–68*B* (1934). **VIII. Relationship between rate of drying and the liquids contained in kaolin.** *Ibid.*, **37** [12] 756–64*B* (1934).—Kaolin was dried, cooled, and immersed in various liquids after which the rate of drying was studied. The results are shown in tables and diagrams. For Part V see "Researches—" *Ceram. Abs.*, **13** [11] 305 (1934). M.V.C.

Electric micrometer for measuring coefficients of thermal expansion of various ceramic materials. ADOLF HEINZ AND HORST KOTTAS. *Sprechsaal*, **68** [4] 49–51; [5] 65–66 (1935).—Details of procedure are given. Illustrated. M.V.C.

Firing rotary melting furnaces and their application in metallurgy. BOUTIGNY. *Chaleur & ind.*, **15** [169] 995–1008 (1934).—B. discusses the principles of firing rotary furnaces and their use for casting steel and special iron, bronze and copper, nickel and cupro-nickel, the recuperation of the oxides of lead, tin, and antimony, aluminum, and fusing enamels. M.V.C.

Graining enamel. OSKAR KERSTAN. *Glashütte*, **64** [48] 793–94 (1934).—Details of the method of graining enamel with water and its superiority over the compressed air method are given. M.V.C.

Machinery and pottery design. J. F. PRICE. *Pottery Gaz.*, **60** [693] 363–69 (1935).—P. takes up the influence of design upon machine production in the pottery industry from the standpoint of a designer influencing the trend of machine development. Pottery's possibilities, its competitors, costs of production, craftsmanship, etc., are discussed. E.J.V.

Magnetic separator uses alternating current. MAGNETIC MANUFACTURING CO. *Eng. Mining Jour.*, **136** [1] 52 (1935).—The alternating current provides a high magnetic agitation or pulsation (120 cycles per second on 60-cycle current) which tends to separate or cleanse the magnetic material thoroughly from nonmagnetic. J.L.G.

Optical instruments and measuring devices. F. JENTZSCH AND H. FUNK. *Physik*, **3** [1] 31–56 (1935). W.M.C.

Optical lever and furnace for thermal-expansion measurements using small specimens. H. GOULBOURNE JONES. *Jour. Sci. Instruments*, **11** [10] 325–26 (1934).—Specimens 0.15 cm. long or rolled specimens 0.03 cm. thick can be measured. Measurements can be made down to 8.2×10^{-6} cm. Illustrated. J.L.G.

Roller crushers. N. P. VAGANOV. *Ogneuporui*, **2** [10] 44–46 (1934).—Theoretical formulas of the work of roller crushers are shown. The required dimensions of the rollers, where D = diameter of rollers, d = diameter of body crushed, L = width of rollers, are $D \geqslant 20d$ to $22d$; $L = D$ (0.3 to 0.7). The output of the crusher, where Q = output in T./hr., n = rotations per min., l = length of the rollers, $2e$ = distance between rollers, ψ = rate of use of the rollers, γ = volume weight of material in kg./l or T./m.^{3}, is $Q = 60 \cdot \pi \cdot D \cdot n \cdot l \cdot (2e) \cdot \psi \cdot \gamma$; $\psi = 0.6 \frac{(2e)}{d} + 0.15$. The motor power required (N = power required, σ = strain arising under influence of deformation, $2R$ = diameter of rollers, E = modulus of elasticity of the material) is

$$N = 1.3 \frac{\sigma^2 \cdot L \cdot R \cdot r \cdot n}{150{,}000\sqrt{E}} + \frac{L \cdot R^2 \cdot n}{78{,}000{,}000}$$

P.B. & E.S.

Torsion viscometer. A. GALLENKAMP AND CO. *Jour. Sci. Instruments*, **11** [10] 328 (1934).—A torsion viscosimeter intended for the routine testing of viscous materials such as condensed milk, jellies, oils, and greases is described and illustrated. The instrument will give comparative results only and not an absolute determination of viscosity. J.L.G.

Transmission by gearing and motors with reducers applied to ceramic machines. PIERRE RENAULT. *Rev. mat. constr. trav. pub.*, No. 302, pp. 200–202*B* (1934).—The application of direct action to ceramic machines by motor and reducer will bring, because of the economy, marked changes in the technique of installation of machines and the transmission of motor power in ceramic plants. Further details are given. For previous abstracts see *Ceram. Abs.*, **14** [3] 78 (1935). M.V.C.

PATENTS

Apparatus for determining the coefficient of expansion of solids. W. & J. GEORGE, LTD., AND F. P. BOUGH. Brit. 424,017, Feb. 27, 1935.

Apparatus and method for preparing fused materials. WILLIAM HOGENSON (Chicago Vitreous Enamel Product Co.). U. S. 1,993,964, March 12, 1935.

Process for manufacture of ceramic ware. A. E. R. WESTMAN. U. S. 1,993,047, March 5, 1935. A process comprises preparing a plastic mass comprising clay and water, contacting the mass with a permeable support, and materially reducing the water content of the plastic mass by the application of sufficient mechanical pressure to expel water therefrom through and beyond the support.

Kilns, Furnaces, Fuels, and Combustion

Ashes in coal. THOS. G. ESTEP. *Heating, Piping & Air Conditioning*, **6** [12] 520–24 (1934).—E. reviews the results of various recent investigations on coal ash and indicates the application of this knowledge to promote increased efficiency in heating with coal. Although coals with ash-fusion temperatures below 2400°F are usually termed clinkering coals, E. shows that they can be burned without clinkering if care is taken to insure ready access of air to the bottom of the fuel bed to cool the ash which has settled below the hot fuel bed. Coals high in ash are no more likely to clinker than are those low in ash. Coals with some ash protect the grates from the hot fuel bed and allow a slow fire to be carried when desired. As yet no practicable flux for addition to domestic fuels has been worked out. The viscosity of coal-ash slag varies widely even in slags with the same fusing temperature. Weathering of coal in the open tends to increase the fusion point of its ash. Illustrated by graphs. J.L.G.

Calculations of heat exchangers. LAFFARGUE. *Chaleur & ind.*, **15** [169] 1180–89 (1934).—The definition of heat exchangers and the distinction between recuperators and regenerators are given. Calculations and diagrams illustrate the discussion. M.V.C.

Cause of changes in rate of some gas reactions. MORRIS W. TRAVERS, ROBERT V. SEDDON, AND PETER F. GAY. *Nature*, **134** [3391] 662 (1934). J.L.G.

Cement rotary furnaces: thermal balance and losses. VOGEL. *Chaleur & ind.*, **15** [169] 1029–36 (1934).—The thermal balance shows that 18.4% of the losses is due to waste gases and 16.9% is due to radiation. M.V.C.

Ceramic firing processes. I. Problems and working methods. OTTO KRAUSE AND EBERHARD KEETMAN. *Sprechsaal*, **68** [1] 1–3 (1935).—Problems connected with a study of the effect of ceramic firing and its factors (such as firing temperature, duration of firing, and furnace atmosphere) on changes in the structure, processes of sintering, and properties of ceramic products are analyzed, and the precautions taken to circumvent the difficulties that arise are dealt with. M.V.C.

Ceramic kilns and drying equipment. H. JORDAN. *Ber. deut. keram. Ges.*, **15** [7] 357–69 (1934).—A detailed technical description of the newer developments in ceramic kilns and driers is presented. E.J.V.

Combustion method. L. STOUFF. *Rev. universelle mines*, No. 2, p. 44 (1934); abstracted in *Verre & Silicates Ind.*, **5** [7] 134 (1934).—The method of firing, called the process of "gaseous suspension," endeavors to realize the principle of rational combustion. The combustion chamber is of a "drum conical" shape and is filled by a homogeneous ascending current of air of combustion. A grain of fuel introduced into this chamber remains in suspension; the driving of the ascending gas counterbalances the weight of the grain. The grain will find a level of equilibrium depending on its weight, density, and shape. The same principle is realized with a large quantity of grains. When bringing to incandescence this "mist of particles," the combustion will be continuous with a regular supply of grains in proportion to the supply of air. The pressure of the air of combustion is sufficient to carry the fuel; the smaller the grains of the fuel, the easier the suspension will be. M.V.C.

Fundamentals, rules, and examples of computing furnaces. I. H. SCHWIEDESSEN. *Arch. Eisenhüttenwesen*, **8**, 231–38 (1934).—Formulas and equations are given for computing furnaces, the calculations being based on the volume of the elements present in the fuel. The influence of the charge is taken into consideration by separate formulas. W.M.C.

Furnaces for firing glazed ware. LUDWIG SCHIELE. *Tonind.-Ztg.*, **58** [87] 1059–60 (1934).—Muffle furnaces with ascending and horizontal firing are discussed. Illustrated. M.V.C.

Heating with heavy oil in industrial furnaces. J. DUZAN. *Chaleur & ind.*, **15** [169] 987–95 (1934); abstracted in *Verre & Silicates Ind.*, **5** [22] 431–32 (1934).—The firing technique and advantages of firing with heavy oil and the operation of a porcelain kiln with a 35-sq. m. capacity are discussed. In the porcelain kiln, firing was completed in 18 to 20 hr., instead of 36 to 38 hr. when coal was used, and the quality of the products was better. M.V.C.

Heat-insulating materials in the construction of industrial furnaces. M. V. KRASNOSELSKIĬ AND A. A. SHCHUKIN. *Metallurgia*, **8** [10] 21–41 (1933); abstracted in *Chem. Zentr.*, **i**, 135 (1935).—Thermal balances of industrial furnaces and the distribution of heat losses in them are discussed. Methods for lowering thermal losses by increasing the thicknesses of walls, arrangement of air insulating layers, and the utilization of insulating materials are dealt with. Diatomite as insulating material and the production of diatomite brick in U.S.S.R. are described. Calculations of the passage of heat through furnace walls insulated with diatomite brick and other insulating materials are given. M.V.C.

Heat losses through walls in ceramic furnaces and their elimination. E. PRAETORIUS. *Tonind.-Ztg.*, **58** [100] 1220–21; [101] 1235–37; [102–103] 1249–52; [104] 1263–64 (1934).—Researches on heat losses in ceramic furnaces showed the following results: (1) The amount of thermal losses through walls is due not only to losses produced by radiation but also to the "accumulation" of heat by the masonry, especially when firing for a short time. (2) In continuous operation or firing these losses amount to 20 to 30% of the total heat losses. (3) The increase of the masonry thickness lowers the radiation losses but increases the losses due to the accumulation of heat by it. (4) The use of an outer insulation has the same effect but not to such an extent as the increase of the wall thickness. The outside insulation is economical only in furnaces fired continuously (chamber and tunnel kilns). (5) The economy obtained by an insulating coat depends not only on savings in fuel but also on the price and quality of insulation and the time of operation of the furnace per year. The usual thicknesses are 10 to 15 cm. (6) New furnaces should always be provided with insulation; the same is true when reconstructing furnaces. (7) High-quality insulating materials with a low conductivity are more advantageous than those of an average quality. It is much better to have thin layers composed of high-quality materials than thick layers of materials of lower quality, because they

have a high specific gravity which greatly increases heat losses due to accumulation. Tables and diagrams illustrate the discussion. M.V.C.

Heat and structure tension in fired ceramic bodies. W. STEGER. *Ber. deut. keram. Ges.*, **15** [3] 139–60 (1934).—While glassworkers can determine strains and tension in their finished products, ceramic bodies can not so easily be checked for strain. Tension or strain in a finished product is not predictable from the factors for the individual components. This is due not only to the reactions of the various components on each other but also to a lack of homogeneity in the body which has a great effect on the strained conditions in the body. E.J.V.

Luminous flame burners in glassmelting. F. G. SCHWALBE. *Ind. Heating*, Oct., pp. 79–84; Nov., pp. 143–46; Dec., pp. 203–205 (1934).—Principles of heat transfer by flames and the advantage of luminous flames in firing furnaces are explained. Practical figures on heating values of the most commonly used gases and heat conductivity of glass at different temperatures are given; the calculation of burners is illustrated. M.H.

Prandtl's equation of heat transfer. J. KUPRIANOFF. *Z. tech. Physik*, **16** [1] 13–15 (1935).—A modified form of this equation has been derived which was found to be in good agreement with recent experiments. W.M.C.

Preliminary results of reconstructed tunnel kilns of plant No. 2 of "Building Materials" Trust. A. D. ZEPIN. *Stroitel. Material.*, No. 8, pp. 4–8 (1934). P.B. & E.S.

Processes taking place in annular kilns during firing. F. SIEKMANN. *Tonind.-Ztg.*, **58** [95] 1156–57 (1934).—The behavior of temperature, gas volume, gas weight, gas velocity, and draft in the kiln is discussed. Diagrams illustrate the discussion. M.V.C.

Pulverized coal and colloidal fuel. H. D. TOLLEMACHE. *Iron Coal Trades Rev.*, **126** [3395] 453–54 (1933); abstracted in *Mech. Eng.*, **55** [6] 379 (1933).—Colloidal fuel composed of pulverized coal and oil is compared in detail with coal and oil as individual fuels. F.G.H.

Putting brilliance on White House dinner set. EUGENE D. MILENER. *Amer. Gas Assn. Monthly*, **17** [1] 14–15 (1935).

Rich gas mixed with producer or poor gas for firing large furnaces. EMILIO DAMOUR. *Chaleur & ind.*, **15** [169] 941–44 (1934).—The mixing of coke-oven gas and city gas to enrich poor gas or blast-furnace gas (1) yields a much higher value than that indicated by the calorific power and (2) increases the power of output of a furnace. Details of experiments made with a large glass tank furnace, a pot furnace, and a Martin furnace are given. M.V.C.

Spectra and latent energy in flame gases. W. T. DAVID. *Nature*, **134** [3391] 663 (1934). J.L.G.

Theory of firing. F. D. STAROSTIN. *Ogneuporui*, **2** [11] 35–43 (1934).—A critical survey of the existing theories of firing of ceramic ware is presented. A series of constants (modulus of elasticity of unfired and fired ware at different temperatures, constants of kinetics of polymorphous transformation, etc.) should be determined; their availability will make it possible to compute a scientific firing curve for every kind of ware. P.B. & E.S.

Thermal insulation of industrial furnaces. H. P. *Verre & Silicates Ind.*, **5** [23] 443–44 (1934).—Data are given to show the advantages of the insulation of industrial furnace crowns. M.V.C.

Water-smoking period and its control. J. L. CARRUTHERS. *Jour. Amer. Ceram. Soc.*, **18** [4] 113–17 (1935).

PATENTS

Kiln for firing brick. A. HABLA. Czechoslo. P. 4655–31 (Appln. Oct. 15, 1931); *Stavivo*, p. 366 (1933).—By erecting partitions between two permanent or temporary walls a zigzag kiln is formed. R.B.

Muffle furnace. T. E. BRIDGFORD (Gibbons Bros., Ltd.). U. S. 1,989,265, Jan. 29, 1935.

Geology

Barite deposits of the sinks district, Bibb County, Alabama. WALTER B. JONES AND T. N. MCVAY. *Econ. Geol.*, **29** [8] 761–66 (1934). J.L.G.

Crystalline structure of manganite. J. GARRIDO. *Compt. rend.*, **200** [1] 69–71 (1935).—An exact study of the lattice structure of manganite ($Mn_2O_3 \cdot H_2O$) was made with X-rays to determine the difference from diaspore ($Al_2O_3 \cdot H_2O$) and goethite ($Fe_2O_3 \cdot H_2O$) which are very similar in structure. The lattice parameter was found to be a = 8.84 Å, b = 5.23 Å, and c = 5.74 Å. M.H.

Dolomite in ceramic mixes and enamels. LOUIS VEAUX. *Rev. mat. constr. trav. pub.*, No. 304, pp. 1–4*B* (1935).—The practical application of dolomite in the ceramic industry is discussed with examples. M.V.C.

Genetic significance of hydrothermal kaolin synthesis. W. NOLL. *Centr. Mineral. Geol.*, **A**, pp. 80–84 (1934); *Mineralog. Petrog. Mitt.*, **45**, 175–90 (1934); abstracted in *Chem. Zentr.*, **i**, 2914; **ii**, 1755 (1934).—The formation of kaolin in the majority of cases occurs under low pressure and low temperature, although it sometimes takes place at definitely higher temperatures. The possibility of the hydrothermal formation of kaolin is supported by the synthesis of kaolin at high temperatures. Feldspars, the initial material of kaolinization, can be artificially decomposed in the presence of a strong HCl solution. In the natural decomposition, the feldspar lattice loses its alkalis and some SiO_2 from the effect of acid solutions; the Al_2O_3 and SiO_2 compounds react directly into kaolin as soon as they are liberated from the alkalis. The surplus silica is removed during or after the kaolin reaction. M.V.C.

Interaction of clay with liquids and crumb formation in soils. E. W. RUSSELL. *Trans. Roy. Soc.* [London , **233**, 361 (1934).—Clay particles react appreciably with the molecules of polar liquids but not or only slightly with nonpolar liquids. Independent evidence is given for the conclusion that the Mg ions on the clay have about seven and the Ca ions about three more molecules of water of hydration than the Na or K ions. Clays interact with water and organic liquids containing a polar group by causing a contraction of the liquid. For homionic clays saturated up to

p_H 7 with base, this contraction is nearly proportional to the number and the mean charge density on the surface of the exchangeable ions on the clay and, to a less extent, it varies with a parameter specifying the shape of the titration curve of the clay. These results have been interpreted on the hypothesis that cations can orientate polar molecules of the dispersion liquid around them, and this power is proportional to their surface density of charge. This power is also possessed by the free negative charges on the clay particle. When the dispersion medium has nearly all been removed the cations bind the negative charges on two clay particles together by bridges of strongly orientated molecules of the polar dispersion liquid. (*T.C.S.E.*)

Kaolinite in Illinois coal. CLAYTON G. BALL. *Econ. Geol.*, **29** [8] 767–76 (1934).—B. found that secondary deposits of kaolinite may constitute more than 90% of the separable mineral matter in a coal bed. This mineral is the most prevalent mineral constituent of coal No. 6 in Franklin County. J.L.G.

Occurrence and winning of kaolins. R. LORENZ. *Ber. deut. keram. Ges.*, **15** [5] 241–49 (1934).—A description of the occurrence of kaolin at Pomeisel and its winning and preparation is presented. Results of firing tests on the prepared kaolin are listed. Illustrated. E.J.V.

Petrology of the Pennsylvania shales and noncalcareous underclays associated with Illinois coals. I. RALPH E. GRIM. *Bull. Amer. Ceram. Soc.*, **14** [3] 113–19 (1935).—X-ray studies by P. F. Kerr and chemical studies by O. W. Rees are included.

Portable sedimentary laboratory. F. R. S. HENSON. *Bull. Amer. Assn. Petroleum Geol.*, **18** [12] 1705–1709 (1934).—Portable equipment for the preparation of thin rock sections, mineral residues, and micro-fossil concentrates is described. The whole is contained in a box measuring 62 x 21 x 35 cm. G.M.H.

Water combination in the kaolin molecule. II. X-ray investigation. W. BÜSSEM AND W. DAWIHL. *Ber. deut. keram. Ges.*, **15** [9] 459–63 (1934).—X-ray studies show that a portion of mica like material is in the raw material. The decomposition of the kaolin molecule by the formation of a compound of the type R_2O–Al_2O_3–$3SiO_2$ on treatment with lithium nitrate occurs at 500°, while on treatment with potassium, sodium, or rubidium nitrate it does not occur until about 700°. The compound of the type $0.5R_2O$·Al_2O_3·$2SiO_2$ is discussed as to the lack of space lattice interference and the structural synthesis of the raw material. For Part I see *Ceram. Abs.*, **12** [12] 434 (1933). E.J.V.

BOOKS AND BULLETINS

Dip and Strike Problems Mathematically Surveyed. KENNETH W. EARLE. x + 126 pp. Thomas Murby and Co., London, 1934. Price 12s 6d net. Reviewed in *Nature*, **134** [3392] 684 (1934).—This is a text for the student of structural geology. J.L.G.

Geophysical prospecting abstracts. F. W. LEE. *Bur. Mines Periodical Service Rept.*, G. A. 68, 23 pp. 10¢. R.A.H.

Metamorphism: A Study in the Transformation of Rock-Masses. ALFRED HARKER. ix + 360 pp., 185 figs. E. P. Dutton & Co., New York, 1934. Price $5.90. Reviewed in *Econ. Geol.*, **29** [8] 781–83 (1934). J.L.G.

Principles of Historical Geology from the Regional Point of View. RICHARD M. FIELD. xii + 283 pp., 10 plates. Princeton Univ. Press, Princeton, N. J. Briefly reviewed in *Nature*, **134** [3396] 829–30 (1934).—The book contains several minor errors according to the original reviewer. J.L.G.

Report of the Committee on the Measurement of Geologic Time. ALFRED C. LANE, Chairman. Presented at National Research Council Meeting of the Division of Geology and Geography, Washington, D. C., April, 1934. Reviewed in *Bull. Amer. Assn. Petroleum Geol.*, **19** [2] 302 (1935). Mimeographed. 86 pp. G.M.H.

Chemistry and Physics

Basic salts. II. Simple basic chlorides of bivalent heavy metals. ERICH HAYEK. *Z. anorg. allgem. Chem.*, **210**, 241–46 (1933).—Bivalent heavy metals in general form basic chlorides of the type $M(OH)_2 \cdot MCl_2$. The new compounds $Mn(OH)_2 \cdot MnCl_2$, $Sn(OH)_2 \cdot SnCl_2$, and $Fe(OH)_2 \cdot FeCl_2$ and mixed crystals of these with $Zn(OH)_2 \cdot ZnCl_2$, $3CdCl_2 \cdot ZnCl_2 \cdot 8H_2O$, and $2HgCl_2 \cdot 5ZnCl_2 \cdot 12H_2O$ are described. For Part III see *Ceram. Abs.*, **14** [4] 101 (1935). (*C.A.*)

Ceramic coloring materials. I. Spinel coloring materials and spinel. OTTO KRAUSE AND WERNER THIEL. *Ber. deut. keram. Ges.*, **15** [3] 101–10 (1934).—The spinels for comparison were prepared pure. The results of crystal-size measurements were compared with those of other authors and discussed. **II. Formation and structure relations of spinel coloring materials.** *Ibid.*, **15** [3] 111–27 (1934).—The X-ray study shows that the production of coloring materials by the simple mixing of nonwater-soluble oxides alone with the addition of fluxes is not suitable, as only in a few simple cases do they change to coloring materials of definite structure. The method of mixing equivalent quantities of salt solutions or the melts of equivalent amounts in water of crystallization is exceptionally practicable. If production of spinel-mixed crystals with excess R_2O_3, *e.g.*, with cobalt blue, is desired, the R_2O_3 component must be used in a form suitable for the formation of its γ-modification. The decorative tests showed that more beautiful and more resistant colors were obtained if the coloring materials were completely a spinel or with excess RO or R_2O_3 as homogeneous mixed crystals. **III. Reflections on the stability relations of spinel coloring materials.** *Ibid.*, **15** [4] 169–78 (1934).—Observations on the stability relations of ceramic spinel coloring materials are made on the difference in the lengths of the elementary bodies, the values being obtained by measurement and on the basis of structure. These differences (contractions), which are numerically about the same for chromites and ferrites and lower than for the aluminates and which, within this series, decrease to the magnesia spinels, are traceable to the varieties of the oxygen parameters and ionic deformation and lead to the conclusion of the relationship of the coloring material stability to the tension relations of its crystal lattice. Further, it must be concluded from observations on the formation of spinel coloring materials that there is a

tendency toward the formation of a spinel with the least inner tension. These conclusions were confirmed in suitable tests on iron aluminate, iron chromite, and magnesia ferrite, and indications were shown that more exact results are to be expected. E.J.V.

Ceramic diaphragm structure. A. VAŠÍČEK. *Bull. Tech. High-School, Brno*, Vol. 7, Paper No. 29 (1933). R.B.

Determining carbon and hydrogen in substances of a bituminous or pyro-bituminous nature occurring in shales. H. W. HOOTS, A. L. BLOUNT, AND P. H. JONES. *Bull. Amer. Assn. Petroleum Geol.*, **19** [2] 293–95 (1935).—Apparatus and procedure are briefly described. G.M.H.

Determining potassium in silicates with a cobalt-nitrate complex containing silver. G. V. TANANOIYES. *Trans. Ukrain. Sci. Research Inst. Bldg. Materials* [U.S.S.R.], 10 (1931); abstracted in *Sprechsaal*, **68** [5] 70 (1935).—A rapid method (exactness 2%) for determining potassium in silicates is described. Potassium is precipitated with a sodium-cobalt-nitrite solution containing lead or silver salt. The complex salt precipitated, $K_2PbCO(NO_2)_6$, is never pure; however, the use of a "standard factor" ascertained experimentally through the determination of a known amount of K-salts permits the use of this method. M.V.C.

Determining SiO_2 in water glasses. S. S. KOROL AND V. M. KALUISKAYA. *Zavodskaya Lab.*, **3** [10] 908 (1934).—A modification of the usual Siegel method is based on the reaction, $SiO_2 + 6NaF + 4HCl = Na_2SiF_6 + 4NaCl + 2H_2O$; to accelerate this reaction, an excess of HCl is added and this excess is titrated back with NaOH. To avoid the reaction of NaOH with sodium fluosilicate, the latter is converted to a slow soluble form with the aid of KCl in a volume of alcohol identical with the volume of the mixture. P.B. & E.S.

Effect of heat on some natural manganese oxides. ST. PAVLOVITCH. *Compt. rend.*, **200** [1] 71–73 (1935).—The transformations undergone by hausmannite, polianite, and manganite when subjected to thermal analysis are described in detail. M.H.

Grades of strength. G. MEYERSBERG. *Giesserei*, **21** [29–30] 313–14 (1934).—Three grades of strength are distinguished in a material: strength as revealed and measured by its mechanical properties, strength of the lattice, and strength of the atomic nucleus. Changes in the character of the first according to whether stress is referred to unit of section or to nominal stresses are pointed out; the curves become steeper, the more flow of material is prevented, *e.g.*, by notching. Complete prevention of flow means perfectly brittle fracture occurring at "ultimate strength." The ultimate strength is always below what can be expected from the "lattice strength"; this is probably due to defective places in the crystal structure. Numerical values of lattice strength have not yet been determined with certainty. Still less is known of the "atomic strength," the strength of the nucleus of the atom which is still higher than the lattice strength. The relation of mechanical conditions in the production of a material largely determines its strength as measured by the first of the grades of strength. M. H.

Gravimetric analysis of lead dioxide in minium. E. SCHÜRMANN AND CHARISIUS. *Mitt. deut. Materialprüfungsanstalt.*, No. 17, p. 272 (1934); abstracted in *Sprechsaal*, **67** [52] 798 (1934).—Lead dioxide is treated with chrome-3-chloride or chrome-3-acetate in a weak acetic acid solution (in the presence of sodium acetate): $3PbO_2 + 2CrCl_3 + 2H_2O = 2PbCrO_4 + PbCl_2 + 4HCl$. When the analysis is made accurately, only lead dioxide is transformed into neutral lead chromate while lead oxide does not react. The lead chromate weighed can be tested volumetrically for its chromic acid content. M.V.C.

Increase of plasticity by addition of bentonite. K. ENDELL AND C. WENS. *Ber. deut. keram. Ges.*, **15** [6] 271–80 (1934).—Experiments on plasticity of clays with additions of calcium and sodium bentonites are described. It is possible to differentiate between calcium and sodium bentonites by the complex ion coating on the clay particles. X-ray analysis identifies the montmorillonite lattice but not the manner in which the cation is bound to the surface. This must be done by ammonium chloride interchange or electrodialysis. Small additions of calcium bentonite (1 to 5%) increase the plasticity of nonplastic materials greatly without appreciably affecting the drying shrinkage. Sodium bentonite increases the drying shrinkage considerably without appreciably increasing the plasticity. The dry stability is increased by both. An addition of 1 to 5% bentonite has only a slight effect on the melting point, the softening under pressure, and fired color of the ceramic materials treated with it. E.J.V.

Infra-red spectra of silica. D. G. DRUMMOND. *Nature*, **134** [3393] 739 (1934).—The results of an investigation of the infra-red absorption of transparent silica between 1.0 and 7.5 μ are summarized. Many new bands were found and one at 2.72 μ and several between 2 and 4 μ, reported by other investigators, were absent. Of 14 bands for fused silica, 11 can be represented as harmonics of 5 frequencies. Quartz spectra are more complex but bands corresponding to those of fused silica were picked out, associated frequencies deduced, and further bands ascribed to additional harmonics and combinations. The numerical relationships between the five frequencies are given with the statement that they may not be true fundamentals but may be formed from a simpler set of frequencies. Relationships between the five frequencies and the far infra-red spectrum and the Raman effect are given. J.L.G.

Laws of soil colloidal behavior. I (incorrectly numbered XIV). Aging of colloids and base exchange. A. J. PUGH. *Soil Sci.*, **37** [5] 403–27 (1934).—The increased activity of the H ion during the aging of aluminum hydroxide and silicate was studied, together with the flocculation in barium acetate solution and diminished adsorption capacity on aging. Both the hydroxide and silicate were synthesized by hydrolysis of the chloride, the oxygen of the hydroxyl group or the silicate group combining with the aluminum ion through the lone pair of electrons of the oxygen. This is by definition a covalent bond, but the molecules of the freshly prepared colloids are unsaturated, the aluminum having only 6 shared electrons but requiring 8 for stability. The hydrogen, because of its small volume and consequent high mobility, dissociates in a water suspension, and the lone pair of the oxygen are transferred to the aluminum, increasing the number of shared electrons by 2, the aluminum becoming quadrivalent and saturated. This leads to a continuous polymerization until all the ma-

terial is exhausted and gives an unsaturated molecule. The freshly prepared sol is stable in a solution of barium acetate, but the 3 weeks-old sol flocculates rapidly because of the increased size of the particles. It is suggested that a particle of Ba-colloid may thus be actually smaller than that of a H-colloid, provided the barium is added to the freshly prepared colloid. The bearing of this on current theories of base exchange and the structure of clay is briefly discussed. The strong adsorption of the H ion is attributed to the fact that it is the only cation that can form a covalent bond with two shared electrons, whereas the other cations must be held by electrostatic attraction, as they require a group of 8 for stability. Iron and aluminum when combined with bentonite are not afterward removed by leaching with ammonium chloride, the combination with the lone pair of the oxygen taking place with the unsaturated hydroxides. G.R.S.

Log sector for the quantitative analysis of precipitates. E. G. Knowles and L. C. Martin. *Trans. Faraday Soc.*, **31** [2] 502–508 (1935).—Quantitative measurements of chemical co-precipitation are attacked by the method of quantitative spectroscopic analysis, and the results are given for the precipitates of zinc with copper when the latter is precipitated as the sulfide from solutions of varying acidity. G.R.S.

Penetration of liquids in capillary voids of fired ceramic bodies. A. Vašíček. *Stavivo*, p. 93 (1934).—The diameter of the pores of the diaphragms P_1, P_{10}, and P_{20} was measured in $P_1 = 0.622$, $P_{10} = 0.874$, $P_{20} = 1.66$. The parameters of the parabolic curves for penetration were measured and calculated. Both values differ, as the pores are not really circular (as is presumed by the formula) and as the different pores are not straight lines through the body but form a network. The liquid evaporates during the penetration and stops some of the pores with dust. J. Matějka (*Stavivo*, p. 165 (1932)) has shown a relation existing between penetrability and permeability. R.B.

Petrographic methods in slag examination. R. Graham and R. Hay. *Jour. Roy. Tech. Coll. Glasgow*, **3**, 241–43 (1934).—Some optical properties were recorded of MnO-SiO_2 mixtures prepared in conjunction with other work ("Binary—" *Ceram. Abs.*, **13** [10] 274 (1934)). The refractive index was determined on the mixtures in powder form, the preparation of thin sections being difficult on account of the friable nature of the specimens. (*J.S.G.T.*)

Relations of various physical, chemical, and technical properties of clays. H. Salmang and J. Kind. *Ber. deut. keram. Ges.*, **15** [7] 331–57 (1934).—Using P. Vageler's method, the complex-ion coating was determined in the cases of eleven clays and two kaolins. A very low sorptive value was found for the kaolins, china clays, silica clays, and light clays. The fat clays had a high sorption capacity. The Andreas pipet method was used to determine the grain-size division of the clays. The kaolins, lean clays, and light clays were considerably more coarse grained than the fat clays and one china clay. The determination of hygroscopicity on the thirteen clays showed it to be lowest with the kaolins and china clays. No evident relationship can be found between the grain-size distribution of the clays and the complex-ion coating or between the grain-size distribution and the hygroscopicity. The amount of sorptive cation and the water-vapor absorption over 10% sulfuric acid show a definite relationship insofar as clays with a low complex-ion coating have a low hygroscopicity and clays with a high sorption value have a high hygroscopicity. The findings of Vageler can not be strictly confirmed. Using the Pfefferkorn method for determining plasticity it was found that there is a definite relation between the fine clay content of a clay and its best plasticity. The comparison of the total sorption capacity with the physical properties of the raw clays shows only an indication of conformity. With a low T-value the plasticity, dry strength, and dry shrinkage are low; with a high T-value they are high. Shrinkage, porosity, temperature of softening under load, cold compressive strength, thermal expansion, and thermal conductivity were determined on the clays fired to 1300°C. The thermal conductivity of the clay bodies was very different for the same grog content. The influence of grain size and the behavior of the fine clay could in no case be clearly determined. Zettlitz kaolin was resolved into five fractions and the separate fractions were tested for grain-size distribution, plasticity, drying shrinkage, dry strength, porosity, and thermal conductivity. The degree of fineness greatly influenced the physical properties of these fractions. With increasing fineness of grain the plasticity, dry strength, and drying shrinkage increased and the porosity and thermal conductivity decreased. In judging clays it is necessary to consider the physical behavior of clays as the sum of the chemical, physical, and physicochemical reactions of the individual components. A strict characterization of a clay on the basis of the magnitude of one or a few of its properties, such as grain-size distribution or complex-ion coating, is not possible. E.J.V.

Reduction of quartz into silicon. M. S. Maksimenko. *Metallurgia*, **7** [10–11] 22–25 (1932); abstracted in *Chem. Zentr.*, **i**, 39 (1935).—Yellow quartz softens at 1600° into a vitreous mass; a reduction of SiO_2 by C occurs at 1460°. An intimate contact of glass with C is, however, necessary for it. The presence of a glass-like phase (Si and SiO_2) brings about the occurrence of gases in the cooler part of the melt and colors the glass gray. An addition of 0.5% water decolorizes the glass markedly and the reaction $Si + 2H_2O = SiO_2 + 2H_2$ takes place. A layer of siloxicon formed with time protects the quartz from a further reduction. A gas-like phase (C-vapors) occurs also in ferrosilicon melts in electric furnaces. The siloxicon layer is destroyed by the arc. Little Si is therefore obtained in resistance furnaces because the gasified Si combines with C to form silicon carbide. Various processes taking place in different zones of electric furnaces are discussed. M.V.C.

Structure and thermochemistry of silicates. I. F. Ponomarev. *Trans. VI Mendeleiev Congress Theoretic and Appl. Chem., 1932*, **2**, 425–51 (1934).—P. gives a survey of our knowledge of the structure of silicates, the study of their atomic structure, and their thermochemical properties. The value of the X-ray method of investigation of silicates is emphasized; the use of this method made it possible to obtain a true knowledge of the important part played by oxygen in silicates and of the dependence of

their stability from the position of oxygen atoms (their "packing") in the structure of silicate molecules. The connection between the structure of silicates and their thermochemical properties is supposed but has not been fixed with sureness. The growing economic importance of the silicate industry brings the necessity of increasing scientific research in this field. P. suggests the idea of silicography as a special science branch studying the structure of silicates. 256 references. P.B. & E.S.

System iron, iron oxide–calcium orthoferrite. E. MARTIN AND R. VOGEL. *Arch. Eisenhüttenwesen*, **8**, 249–54 (1934).—The range investigated comprises $(CaO)_2Fe_2O_3$–$CaO(FeO)_2$–Wüstite–Fe_3O_4–$CaO{\cdot}Fe_2O_3$. Two new types of crystals have been found. Conditions for the formation of free iron and free lime have been studied. W.M.C.

Temperature and radiation measuring errors with ceramic bodies. R. HASE. *Ber. deut. keram. Ges.*, **15** [2] 65–69 (1934).—It is to be observed in thermotechnological calculations that the total possible radiation does not always coincide with the optically measured particle radiating power but is in most cases greater. Experiments to derive the emission values of ceramic bodies in a theoretical way by atomic physical considerations have led to no usable results so that further experimentation is necessary. E.J.V.

Theory of fusion. K. F. HERZFELD AND MARIA GOEPPERT MAYER. *Phys. Rev.*, **46** [11] 995–1001 (1934).—Equilibrium between two phases is in general determined by both phases. Fusion is somewhat unique in that a crystal can not be overheated. The authors developed the exact equation of state of frozen argon, since it has one of the simplest possible crystals. They found that the pressure as a function of the volume at a given temperature has a minimum. This indicates a breakdown of the crystal under the conditions at which the minimum occurs. They interpret the temperature at which this minimum occurs at zero pressure as the melting point of the crystal. It was found that a positive pressure was necessary for the existence of crystalline helium; the numerical agreement, however, is poor. J.L.G.

Volumetric determination of the content of lead dioxide in minium with antimony trichloride. H. BLUMENTHAL. *Mitt. deut. Materialprüfungsanstalt.*, No. 17, pp. 272 (1934); abstracted in *Sprechsaal*, **67** [52] 798 (1934).—The weighed quantity of minium is treated with a measured surplus of an antimony trichloride solution which is gently heated until a complete dissolution of lead oxide occurs. The surplus antimony trioxide is titrated back with $10/N$ potassium bromate solution; toward the end of titration some methyl orange is added as indicator. The standardization of the potassium bromate solution is done with pure antimony metal, which is dissolved in sulfuric acid. M.V.C.

Volumetric determination of Cr_2O_3. I. YUMANOV. *Zhur. Khim. Prom.*, **10** [9] 61 (1933); abstracted in *Chem. Zentr.*, **i**, 3889 (1934).—An amount of chrome salt corresponding to 2.5 or 3 g. Cr_2O_3 is diluted with water; 25 cc. of the solution are treated with 5 to 10 cc. 2 N KOH and 15 or 20 cc. hypochlorite (obtained by saturating a solution of 102 g. NaOH with Cl_2), heated, acidified with 2 N H_2SO_4, and boiled up to disappearance of the Cl reaction. It is cooled and 10 cc. N KI solution are added and titrated with a 0.1 N $Na_2S_2O_3$ solution. M.V.C.

Water softening for bodies and glazes. JOHN H. GRADY. *Ceram. Ind.*, **24** [3] 174–80 (1935).—The softening of waters by use of the lime-soda ash and alum treatments is described in detail, with the chemical reactions involved. E.J.V.

BOOKS

Crystals and the Polarizing Microscope. N. H. HARTSHORNE AND A. STUART. Longmans, Green & Co., Toronto, Canada. 272 pp. Price $5.00. Reviewed in *Can. Chem. Met.*, **19** [2] 47 (1935).—Aspects of crystallography essential to its application in solution of chemical problems are treated. Crystalline state, morphology, and optical properties of crystals are discussed. General methods of attack in typical chemical applications of the polarizing microscope are outlined. E.J.V.

Diffraction of X-rays and electrons by amorphous solids, liquids, and gases. J. T. RANDALL. Chapman and Hall, London, 1934. xii + 290 pp. 197 figs. Price 21s. R. has collected into one volume a useful summary of the data available on the X-ray structure of gases, vapors, organic and inorganic liquids, liquid crystals, and solids such as carbon, glass, and inorganic fibers. These are fields to which R. and his colleagues have made notable contributions. Chapter VI (Part I) deals with glasses and should interest ceramists. In connection with R.'s development of the crystallite theory, the early work of Kittle on crystallization velocity and viscosity and the later theories of Sosman would have been useful. The reviewer (W. Hugill) suggests that factors of significance in the ability of substances to form glasses are to be found in the studies of their temperature-viscosity and temperature-crystallization curves. Strains in glasses have not received consideration by R., although they may play a part in the orientation of groups of atoms. (*T.C.S.E.*)

Introduction to chemistry of silicon. B. S. SHVETZOV. State Ed. Light Ind., Moscow, 1934. 214 pp. Price 4R. This work is a concise description of all combinations of silicon, silica, and silicates. A special chapter deals with the vitreous state of silicates. M. V. CONDOIDE

Introduction to study of colloids (Einfuhrung in die Lehre von den Kolloiden). H. BECHOLD. Theodor Steinkopff, Dresden and Leipzig, 1935. Reviewed in *Trans. Faraday Soc.*, **31** [2] 508–509 (1935).—Seven authors contribute nine chapters entitled (1) what are colloids? (2) preparation of colloids, (3) colloid particles as physical molecules, (4) interfaces and processes at interfaces, (5) sols, gels, and coagels, especially their nonelectrical and nonoptical properties, (6) electrical properties of colloids, (7) separation and purification of colloids, (8) optics of colloids, and (9) X-ray investigation of colloids. G.R.S.

Photographic studies of the qualitative microanalysis of inorganic materials (Bilder zur qualitativen Mikroanalyse anorganischer Stoffe). Collected by W. GEILMANN. 12 pp., 40 plates. Leopold Voss, Leipzig, 1934. Price 8 gold marks. Briefly reviewed in *Nature*, **135** [3403] 88 (1935).—A collection of 240 photomicrographs in 40 plates illustrates the crystal forms of all precipitates commonly met with in qualitative analysis. Forms of crystals, magnifications, and conditions of precipitation are given for all pictures. Microanalysis is valuable for checking the results of chemical analysis and for determinations where only minute quantities of material are available. J.L.G.

Space chemistry of solids (Raumchemie der festen Stoffe). WILHELM BILTZ. x + 388 pp. Leopold Voss, Leipzig, 1934. Briefly reviewed in *Nature*, **135** [3404] 132 (1935).—B. surveys the whole field of the physical chemistry of crystals with particular attention to the determination of the absolute volumes of ions in crystals. Considerable new data are included together with a detailed discussion of their significance. J.L.G.

PATENT

Production of easily melting potash. KALI-CHEMIE A.-G. Ger. 597,582, May 9, 1934. A readily melting potash suitable for use in glassmaking is obtained by the addition of a little boric acid or salt thereof during manufacture. (*J.S.G.T.*)

General

Acid-stable ceramic materials. W. MIEHR. *Feuerungstechnik*, **22** [11] 129–31 (1934).—A review of acid-stable products manufactured in Germany from German raw materials is given. Modern development and production of quartz glass and glassware, acid-stable brick and stoneware, and acid-stable cements are described together with their application in the respective industries. M.V.C.

Activities of the State Institute for Silicate Industry at the technical high-school at Brno for the year 1933. O. KALLAUNER. *Stavivo*, p. 33 (1934).—The staff of the Institute had 4 permanent and 2 temporary high-school workers, 2 workers not belonging to the Institute, 5 laborers and office personnel, and 2 assistant workers. The Institute is financed from the income from tests and investigations. It publishes yearly reports. R.B.

Brickmaking course at the state technical school for ceramics, cements, and lime at Plzeň. JAROSLAV DOSKOČIL. *Stavivo*, p. 189 (1934).—Illustrated. R.B.

Canada's mining industry in 1934. W. H. LOSEE. *Can. Mining Jour.*, **56** [2] 47–51 (1935).—A statistical review of the industry is presented. G.M.H.

Ceramic schools in Czechoslovakia. JOSEF MATĚJKA *Stavivo*, p. 306 (1933).—Czechoslovakia has the following state technical schools for ceramics: (1) ceramic school at Bechyně, (2) school for ceramics, cement, and lime industry at Plzeň, (3) ceramic school at Prague, (4) ceramic apprentice-school at Modrá, Slovakia (5) ceramic school at Teplice-Šanov (German language), (6) school for porcelain industry at Karlovy Vary (German language). The Czechoslovakian Ceramic Society proposes a plan for the reform of these schools and demands the realization of this proposal by the State Department of Schools. R.B.

Chemistry and ceramics of the time of the discovery of European porcelains. W. FUNK. *Ber. deut. keram. Ges.*, **15** [5] 229–41 (1934).—The discoverer of Meissen porcelain and his co-workers had available the achievements of more than a thousand years of technochemical developments, but the science of that time aided them only slightly in reaching their goal. The knowledge of mineral, metallurgical, glass, and ceramic technology of the time, however, served to shorten the time required to discover porcelain. E.J.V.

Control of water softening and boiler feed-water conditioning. H. E. EVANS AND P. HAMER. *Fuel Econ. Rev.*, **13**, 41–42, 44–47, 49 (1934). W.E.R.

Flotation of kaolin. O. SOMMER. *Ber. deut. keram. Ges.*, **15** [6] 317–23 (1934); for abstract see *Ceram. Abs.*, **13** [2] 48 (1934). E.J.V.

Founding and fifty years of the state ceramic school at Bechyně. JOSEF ŠIMÁK. *Stavivo*, p. 225 (1934).—This oldest Czechoslovakian ceramic school was founded in 1884. Within the fifty years 594 students completed the technical courses and 1457 apprentices, the continuation classes. R.B.

Influence of preliminary heating on the technical workability of clays. R. RIEKE AND J. NAUMANN. *Ber. deut. keram. Ges.*, **15** [3] 127–39 (1934).—To determine the changes undergone by the technical workability of clays due to preliminary heating below the decomposition temperature of kaolinite, three plastic clays and one kaolin were heated to 100, 200, 300, and 400°C. Tests were made on the preheated samples for tempering water, degree of rolling out without fracture, plasticity, volume shrinkage on drying, speed of drying, and speed of filtration as a measure of the speed of absorption. All four materials were markedly changed in their properties by the heating, the plastic clays to a greater and the kaolin to a lesser degree. The changes were greater, the higher the temperature of heating. With rising preheating temperature the tempering water decreased, the water content at the "rolling out" point increased, and the plasticity decreased. The volume drying shrinkage, which varied greatly in the unheated materials (22 to 32%), decreased with rising preheating temperature, the difference between the individual materials decreased, and after heating to 400°C all four materials showed the lowest and most nearly equal shrinkage (19 to 20%). In the formed state the speed of diffusion of water and the drying speed of these clays were greater, the higher the preheating temperature. One clay was easily and rapidly dried, the higher it was heated prior to working up. The determination of the speed of filtration, which also served as a measure of the speed of drying in plaster molds, showed a greater or lesser increase with the raising of the preheating temperature. With Zettlitz kaolin and Wildstein blue clay this increase is fairly regular, while with the other two clays the greatest change in structure and also in the speed of filtration occurs between 300 and 400°C. G. Keppeler arrived at similar results in studies of castability of preheated clays, finding that in the preparation of a suitable casting slip the amount of water required was reduced considerably by preheating the clay, so that by preliminary treatment many clays unsuitable for casting were made usable. Collectively the changes produced by preliminary heating tend toward a decrease in plasticity and all the properties connected with it, which are produced by changes in the allophane and organic colloids present, especially in the plastic clays, as well as by the balling up

of the finest particles to larger complexes. In practice the preheating provides the possibility of lowering too great a plasticity. On the other hand, it has been shown that a heating to only 100°C, as occurs in the artificial drying of washed clays or of clays only slightly locally overheated, can have a markedly unfavorable effect on the plasticity. E.J.V.

Modern industrial drive and electrification. R. C. MORTIMER. *Fuel Econ. Rev.*, **13**, 25–32 (1934). W.E.R.

Origin and prevention of silicosis. ANON. *Sprechsaal*, **68** [3] 36–38 (1935).—Abstracts of a series of reports dealing with the origin and prevention of silicosis read at the Meeting of the German Society for Industrial Hygiene, held in Bochum in November, 1934, are given. M.V.C.

Silicosis. M. MACHÉ. *Rev. mat. constr. trav. pub.*, No. 302, pp. 324–25 (1934).—The results of observations made on subjects breathing air filled with cement dust are presented. M.V.C.

Sodium sesquisilicate cleaner. PHILADELPHIA QUARTZ CO. *Metal Cleaning & Finishing*, **7** [2] 95 (1935).—Metso 99, a new high alkaline cleaner, makes solutions that remain effectively alkaline until almost completely spent or neutralized. It contains approximately 36.89 Na_2O, 23.83 SiO_2, and 39.3% H_2O. It is free-rinsing. E.J.V.

State technical school for ceramic industry, cement, and lime at Plzeň. VÁCLAV VEVERKA. *Stavivo*, p. 210 (1934).—This is the first Czechoslovakian technical school with a course on the production of cement and lime. The school has the following departments: (1) brickmaking, (2) fine ceramics, (3) cement and lime. R.B.

Study of crystalline structure by X-ray. Industrial applications. F. R. MORRAL. *Quim. & Ind.*, **11** [128] 202–204 (1934).—Examples are given to show the importance of the study of crystallography for industry, not only to improve products but also for the control of manufacture. M.V.C.

BOOKS

Chemical Formulary. Vol. I. Edited by H. BENNETT. x + 595 pp. The Chemical Formulary Co., Brooklyn, N. Y., 1934. Price $6.00. Briefly reviewed in *Nature*, **135** [3402] 50 (1935).—A folder included with the book contains the names of the suppliers of many of the compositions which appear only under proprietary names in the book. See also *Ceram. Abs.*, **13** [3] 76 (1934). J.L.G.

Materials used in chemical apparatus (Les materiaux constitutifs de l'appareillage chimique). I. SCRIABINE. Ch. Beranger, Paris. 100 pp., 23 illustrations. Price, bound, 30 Belgian F. Reviewed in *Verre & Silicates Ind.*, **5** [22] 432 (1934).—This book is a critical examination of various materials used for chemical apparatus, such as ferrous alloys, metals, nonmetallic minerals, and organic products. Refractory materials, cements, enamels, glass, fused glass, and porcelain are discussed. M.V.C.

Pocketbook for ceramists, 1935 (Taschenbuch für Keramiker). **Vol. I. Notebook-calender.** 30 pp. text. **Vol. II. Technical part.** 386 pp. Published by Keramische Rundschau, Berlin. Price 3.30 M. The technical part contains several articles dealing with (1) a better knowledge of clay substance, (2) ceramic pigments, (3) operating control in enameling works, and (4) shaping glass and ceramic products, besides the usual data and tables of interest to ceramists, list of technical literature, list of supply firms, etc. M. V. CONDOIDE

Theoretical Physics. Vol. II. Electromagnetism and Optics. Maxwell-Lorentz. W. WILSON. Methuen and Co., London; E. P. Dutton and Co., New York, 1934. 315 pp. Price $5.75. Reviewed in *Mech. Eng.*, **56** [3] 190 (1934). F.G.H.

PATENT

Colored silicate granule for roofing and mode of preparing. C. E. HILLERS (Blue Ridge Slate Corp.). U. S. 1,991,981, Feb. 19, 1935. In the manufacture of colored "silicate granules," the process comprises spreading over the surface of granules of an insoluble refractory base a coloring substance of which the color is not destroyed by heating, an alkaline earth metal borate, and a soluble silicate, and thereafter heating the granules to a temperature between about 600 and 1200°F whereby artificially colored granules, at least largely free from tendency to "bloom," are produced.